JOURNAL
OF THE
WASHINGTON ACADEMY OF SCIENCES

VOL. 14 AUGUST 19, 1924 No. 14

GEOLOGY.—*Oceanography in its relations to other earth sciences.*[1] THOMAS WAYLAND VAUGHAN, Scripps Institution, La Jolla, California.

INTRODUCTION

The earth is composed of five more or less concentric shells of material, which are known as the centrosphere, the asthenosphere, the lithosphere, the hydrosphere, and the atmosphere. Oceanography deals primarily with the hydrosphere, or more precisely that part of the hydrosphere contained in the ocean. As the hydrosphere lies between two of the other spheres, its relation to them is physically most intimate, and to understand it, attention may not be confined merely to the adjacent spheres, but it is necessary in imagination to pierce the subjacent lithosphere and proceed to the innermost part of the earth. Oceanography must, therefore, concern itself with all recognized branches of geophysics. In its relations to geology it transcends the bounds usually set to geophysics and passes into the field of biology, for the present ocean holds the key to the significance of the remains of most organisms contained in the stratified rocks and the ocean alone can reveal the nature of many geologic processes which are dependent on the activity of organisms and were operative in the past and are operative at the present time as well.

In an address such as this, it is not possible to review all the subjects I have indicated. The most that I can aspire to do is to point out some of the reciprocal relations between oceanography and other earth sciences. From some of these sciences oceanography may be the principal beneficiary, to others it may make contributions of

[1] Address of the retiring president, WASHINGTON ACADEMY OF SCIENCES, Washington, Jan. 8, 1924.

fundamental importance. Although terrestrial magnetism is one of the important earth sciences, and investigations in it need to be conducted on the sea as well as on the land, I shall only mention it now and shall not give it further consideration in subsequent remarks.

Since my chief scientific activity has been in geology, I may be permitted to emphasize certain geologic relations and to dwell on my beloved bottom muds.

Washington scientific men have been fortunate in that they have recently had opportunities to hear excellent presentations of the results of two kinds of investigations which concern the lithosphere, both where it is and where it is not overlain by water. I refer to Dr. A. L. Day's lecture on the work of the Earthquake Committee of the Carnegie Institution of Washington and Dr. David White's address on the relation of gravity-anomalies to the density of geologic formations. These addresses might be appropriately classified as oceanographic, for both of them dealt with features of the lithosphere, and 71 per cent of the lithosphere lies under the ocean. Doctor Day did project his studies under the waters of the Pacific as far out from the land as the 2,000 fathom curve. To both of these gentlemen I extend my very warm thanks, for they have helped me greatly.

CONFIGURATION OF THE LITHOSPHERE

The total area of the earth according to Sir John Murray[2] is 196,499,000 sq. mi., of which 57,254,000 is land and 139,245,000 water. That is, about 29 per cent of the surface of the earth is land and about 71 per cent of the surface is water. Therefore, 71 per cent of the surface relief of the lithosphere is under the ocean and only 29 per cent above sea level. It will be generally admitted that considered as knowledge of the earth, it is as important to know the configuration of that part of the lithosphere below, as well as that part above, sea level. It is a scientific misfortune that so many of our maps stop the indications of relief at the shore, and it is hoped that this defect may very soon be remedied. In fact, some recently published maps are contoured for the areas both above and below sea level.

Although the configuration of the sea bottom is very inadequately known, there is available a considerable body of information—at least enough to make approximations to actual conditions. The

[2] Murray, Sir John, and Hjort, J., *Depths of the Ocean*, p. 132, 1912.

average depth of the ocean is greater than 12,000 ft. and less than 18,000 ft., while the average height of the land is probably about 2,400 ft.[3] The average ocean depth, therefore, is more than 5 times the average height of the land. The greatest depths of the ocean are a little over 30,000 ft., and somewhat exceed the greatest height of the land. Although from present information it seems that vast areas of the sea-floor are low-lying plains, as most of the eastern Pacific, not all of it is so nearly flat. Two areas adjacent to America in which there is great or considerable relief are the Caribbean region and the sea-bottom off the coast of California south of San Francisco.

Surveys of the sea-bottom supply only empirical data on relief, just as topographic surveys supply only empirical information on the surface features of the land above sea level. How are the features to be explained?

In order to answer this question it is necessary to know all those forces that have caused the earth to deviate from the shape of the theoretical spheroid of revolution and assume that of a geoid. To say that the oceanic basins are underlain by heavier and the continents by lighter material—and this is generally accepted as true—is not sufficient, for the boundaries between the land area and the sea bottom are neither uniformly abrupt nor gradually shelving. Such lack of uniformity in the nature of the boundary is indicative of heterogeneity in the composition of the lithosphere on the one hand and of differential movement on the other. We are, therefore, brought face to face with the problem of the relative weights of the constituents of the different columns of earth substance and the forces that produce differential movements in the earth's crust.

In order to get more information on the density of the material underlying the oceanic basins, gravity determinations at sea are essential. We need for the sea such data as we now have for the land area of the United States, and it is hoped that the recent inventions of Professor Michelson and Dr. F. E. Wright will render the needed measurements practicable.

The study of the dynamics of geologic structures is just as essential in oceanography as in the study of those structures exposed to view on land surfaces. It is well known that the contact zones between continent and ocean are or were sites of great earth movements and adjacent to the sites of such movements there are important volcanic zones. It is necessary only to mention the earthquake

[3] Geikie, A., Textbook of Geology, 4th edit., 1: 49. 1903.

zone and the so-called ring of fire of the Pacific. Radial contraction of the earth seems to be accepted by both the adherents of the Kant-Laplace and of the planitesmal hypotheses of the origin of the earth. Geologists are all convinced of important tangential thrusting near the surface of the earth as well as vertical displacement, although only a few accept the hypothesis of continental drift advocated by Wegener. Notwithstanding agreement about a few general principles underlying geologic structures, relatively little is known. More energetic investigation of these features of the earth should be advocated and supported by geodesists, geologists, and oceanographers. In this connection the work of the Earthquake Committee of the Carnegie Institution of Washington and the coöperating institutions deserves the highest commendation.

The kinds of configuration of the ocean bottom so far considered are the major features, the ocean basins and the more or less submarine ridges with their associated submarine troughs or other depressions. These are the great tectonic features of the ocean on which other forces play.

In the sea, forces are operative which tend to bring the sea bottom to the great base-level of the sea—wave-base. Above wave-base, there is marine erosion which tries to cut down all that stands above it, while below it sedimentation tries to raise the bottom to that level. In some places in the sea agencies tend to fill the sea above wave-base, but such filling, unless the access of new material exceeds in rate the capacity of the waves to cut, must be only temporary. The accumulation of sediment on the sea bottom is not merely due to detritus washed from the land. The most wide-spread deposits in the sea are composed of the remains of organisms which build their skeletons out of substances dissolved in the sea-water. Some of the organic rocks, coral and algal reefs for instance, may have distinctive form.

A number of factors may cause sea-level itself to fluctuate, for a glacial epoch will lower sea-level and deglaciation will raise it; an overdeepening of an oceanic basin will draw the sea downward from the land; and an elevation of the sea-bottom or the accumulation of sediment in the sea will cause the ocean to overflow its shores. The land surface may go down. Currents and waves affect the shore and the bottom below it at least as deep as wave-base—and currents may be effective to even greater depths.

The results of all these processes is to produce a submarine physiography of great complexity. This physiography has not received

the attention it deserves, and until it has been sufficiently studied many phenomena of importance both in understanding the ocean itself and the geologic history of adjacent land areas cannot be adequately explained.

Wave-base has been mentioned. What is the depth of wave-base off different kinds of shores and under different climatic conditions? Except in a very general way, I think it safe to say no one knows. A thoroughgoing investigation of the profile of submarine equilibrium is one of the outstanding needs of the physiographic side of oceanography.

CLIMATOLOGY AND OCEANIC CIRCULATION

Atmospheric circulation and oceanic circulation are comparable in that both are due to the same fundamental causes, viz., the rotation of the earth on its axis, the heat of the sun, and the rugosities of the lithosphere. A subaerial mountain range will affect the movement of the air, while a submarine mountain range will affect the movement of oceanic water. Of course, the air envelops the entire earth, while the ocean covers only about 71 per cent of its surface.

There is a well known reciprocal relation between the air and the ocean. For instance the trade winds tend to drive the surface water of the tropics and subtropics westward and produce a westward-setting surface current. Admiral Pillsbury's explanation of the Gulf Stream is known to all of you and I need not repeat it. The relation between the land climate of western Europe and the temperature of the north Atlantic and between the land climate of the western part of America and the temperature of the adjacent part of the north Pacific is common information. It is also known that a very high barometer will depress the surface of the ocean, which will rise where the pressure is low. There are other generally recognized interrelations between the air and the sea.

It appears that the acquisition of more detailed information on the temperature of the surface waters of the ocean and of atmospheric conditions over the sea may render assistance in forecasting what the weather on the adjacent continents may be. This is a field in which some but not nearly enough work has been done and it should be cultivated more assiduously.

That knowledge of oceanic circulation is of the utmost importance to man in navigation is obvious to everyone, and deficiencies in knowledge are recognized and deplored. Besides the value of the information for such purposes, it is also needed in order to under-

stand the factors controlling the geographic distribution of numerous marine organisms; and knowledge of the interrelation between organisms and currents can be projected backward in time and utilized in interpreting the geologic record.

MARINE SEDIMENTS

Marine sediments cover most of the sea-bottom, about 71 per cent of the earth's surface, and perhaps about 60 per cent of the land surface of the earth, or approximately 90 per cent of the entire surface of the earth. If areal extent is an index of relative importance, the marine sediments are by far the most important class of rocks at the surface of the earth. The thickness of 0.5 mi. assigned to the sedimentary rocks by Professor Clarke in his *Data of Geochemistry* is, I think, too low. The actual thickness is not known, and this, therefore, is another subject that should receive prompt and comprehensive consideration.[4]

I shall not attempt to give any general review of marine sediments. It can not be done in the time permissible for this address. I will state that as the ancient marine sediments can be interpreted only by the light derived from the study of modern sediments, the study of modern sediments is a geologic necessity. I will now pass to the consideration of certain special sediments, viz., calcium-carbonate sediments.

CALCIUM CARBONATE SEDIMENTS

The calcium carbonate contained in or composing sediments is deposited from solutions either in contact with the tissues of organisms or by physical or chemical processes which may or may not be dependent on the activities of organisms. The original source of the calcium carbonate is the crust of the earth. According to F. W. Clarke and H. S. Washington's estimate of 1920[5] the average amount of CaO in the earth's crust is 5.08 per cent and that of CO_2 is 0.102.

Clarke in his *Data of Geochemistry* assumes that the lithosphere consists of 95 per cent igneous and 5 per cent sedimentary rocks. He distributes the 5 per cent of sedimentary rocks as follows: Shales, 4; sandstones, 0.75; limestones, 0.25. In modern deep-sea sediments

[4] See Chamberlain, T. C., *The age of the earth from the geological view point.* Proc. Amer. Phil. Soc. **61**: 254–255. 1922.

[5] Washington, H. S., *The chemistry of the earth's crust*, Journ. Franklin Inst., p. 773, 1920.

$CaCO_3$ is about 32 per cent, and if this ratio should hold for sediments in general, the $CaCO_3$ ratio is much higher than is usually supposed; limestone should be not 0.25, but $5 \times 0.32 = 1.60$, or Clarke's figure may be less than one-sixth of what it should be; or $5 \times 0.2175 = 1.0880$ if all the $CaCO_3$ at the surface of the earth were confined to the deep-sea bottom.

TABLE 1—PERCENTAGE OF $CaCO_3$ IN MODERN DEEP-SEA SEDIMENTS

(Data taken from *Challenger* report)

Area of the Earth: 196,470,700 sq. mi.

(1) NAME OF DEPOSIT	(2) AREA IN SQ. MI.	(3) PER CENT OF AREA OF THE EARTH	(4) PER CENT OF $CaCO_3$	(5) PRODUCTS OF FIGURES IN COLUMNS (3) AND (4)
Red clay	51,500,000	26.2	6.70*	$26.2 \times 6.70 = 175.54$
Radiolarian ooze	2,290,000	1.1	4.01	$1.1 \times 4.01 = 4.41$
Diatom ooze	10,880,000	5.5	22.96	$5.5 \times 22.96 = 126.28$
Globigerina ooze	49,520,000	25.2	64.47	$25.2 \times 64.47 = 1624.64$
Pteropod ooze	400,000	0.2	79.25	$0.2 \times 79.25 = 15.85$
Coral mud, Coral sand	2,556,800	1.3	85.53	$1.3 \times 85.53 = 111.89$
Volcanic mud, Volcanic sand	600,000	0.3	20.49, 28.79 } 29.64	$0.3 \times 29.65 = 8.89$
Green mud, Green sand	850,000	0.4	25.79, 49.78 } 37.65	$0.4 \times 37.64 = 15.06$
Red mud	100,000	0.05	32.28	$0.05 \times 32.28 = 1.61$
Blue mud	14,500,000	7.3	12.48	$7.3 \times 12.48 = 91.10$
		67.55		2175.27

$$\frac{2175.27}{67.55} = 32.20 \text{ per cent.}$$

$$CaCO_3 = 32.20 \text{ per cent; } CaO = 32.20 \times \frac{56}{100} = 18.03 \text{ per cent}$$

$$\text{Concentration of CaO in deep-sea sediments} = \frac{18.03}{5.08} = 3.55 \text{ times the percentage in the average for the earth's crust.}$$

* Mr. George Steiger informs me orally that the $CaCO_3$ in red clay is about 9 per cent.

There is great need for more accurate investigations of the chemical composition of sedimentary geologic formations with the determination of the areas, thickness, and volumes of the different formations so that estimates of the average composition of the sedimentary rocks may be rendered possible. There is strong evidence of con-

centration of $CaCO_3$ in marine formations and it seems that this has escaped the notice of most geologists.[6]

DERIVATION OF CALCIUM FROM THE ORIGINAL CRUST OF THE EARTH

The calcium is derived from the constituents of the original earth substance by the action of acid radicles that would produce soluble calcium salts. These salts are not necessarily $CaCO_3$, which would result from the action of CO_2 on calcium compounds. $CaSO_4$ and $CaCl_2$ are also water-soluble calcium salts and $CaCO_3$ may be formed from either of them by adding a strong alkaline carbonate, such as $(NH_4)_2\,CO_3$, K_2CO_3, Na_2CO_3 or bicarbonate, according to the equation for the sulphate,

$$R_2CO_3 + CaSO_4 = CaCO_3 + R_2SO_4,$$

in which R represents a monovalent alkaline base.

It seems more probable that the principal solvents of Ca were waters containing CO_3 and SO_4 radicles. Clarke in his *Data of Geochemistry* properly attributes the greater amount of solution to carbonated waters, but I wish to enter a plea for more consideration of the sulphate radicle.

Chlorine might be an important solvent were it not for the greater affinity of Na for Cl, especially in the presence of CO_3 and SO_4 radicles. The discrepancy between the amounts of Na and Cl in the rocks and of Na and Cl in the ocean has been recognized by several geophysicists and chemists. There is a known excess of Cl to an amount of about 50 to 1. Several attempts have been made to explain this discrepancy. F. C. Brown[7] postulates that both Na and Cl are derived by radioactive processes, and that in the evolution of these elements the amount of Cl in comparison with the amount of Na in the present average composition of the earth's crust has outrun the proportion of Na and thereby produced the discrepancy. Professor Chamberlin suggests that there may be a return of the sodium of the ocean to the solid state in the ocean sediments[8] and that the discrepant ratios of Na and Cl in the ocean as compared with the parent rocks may thereby be explained. Notwithstanding the discrepant amount of Na and Cl, in whatever way the fact be explained, there is enough

[6] Leith and Mead, in their *Metamorphic Geology* recognize such a concentration of $CaCO_3$.

[7] Brown, F. C., *Sur un preuve que le sodium appartient a une serie radioactive d'élément*, Le Radium, **9**: 4. 1912.

[8] Proc. Amer. Phil. Soc. **61**: 264. 1922.

Na to combine with Cl and we have no important amount of Cl in our atmosphere. Therefore, it seems probable that Cl was not an important acid radicle in the original solutionof Ca from the parent rocks.

Two calcium salts, therefore, seem to be the sources of the important deposits of limestone, viz., $CaSO_4$ and $CaCO_3$.

CHEMICALLY PRECIPITATED CALCIUM CARBONATE IN THE OCEAN

The presence of large quantities of finely divided calcium in the vicinity of the Florida Keys was recognized long ago. In 1863, E. B. Hunt[9] described the so-called white-water periods, which are due to the stirring up of the fine-grained calcium-carbonate muds by storms. Nearly fifty years later Sanford[10] said, "other deposits, such as the marls accumulating on the bottom of Whitewater Bay, have been precipitated from solutions in ways not clearly understood."

My own studies of the problem were an outgrowth of an investigation of the oolitic limestones of southern Florida which I began in February, 1908. From the structure of the oolite grains, the opinion was reached by Messrs. Sanford, Clapp, and Matson and myself that the grains were formed by chemical agencies which caused precipitation of calcium carbonate in concentric shells outward from an interior nucleus.

In the hope that oolite might be found in process of formation, I undertook in the summer of 1908 a detailed study of the bottom deposits in the bays and sounds of the Key region of Florida. Some results of these studies were published in 1910 in a paper by me on the geologic history of the Floridian Plateau.[11] Mr. Geo. C. Matson made mechanical analyses of the bottom samples and described the separates. This was a first attempt at such work by both Mr. Matson and me and in the light of later experience it is crude, but, nevertheless, valuable information was procured.

From the field studies of Mr. Sanford and myself it was found that the soft calcareous mud was in places 10 ft. or more in depth and from the microscopic examination of the finest separates I said "that the accumulation on the sea-bottom of large quantities of

[9] Amer. Journ. Sci., 2d Ser., **35**: 200. 1863.

[10] Florida Geol. Survey., 2d. Annual Report, 228. 1910.

[11] Vaughan, T. W., *A contribution to the geologic history of the Floridian Plateau*, Carnegie Inst. Washington, Pub. **133**: 99–185. 1910.

amorphous calcium carbonate, apparently not of detrital origin, is undeniable."[12]

The interpretation of a part of the finely divided calcium carbonate deposits of the Floridian region as a chemical precipite by Mr. Sanford and me was new and the correctness of our conclusions has been abundantly corroborated by subsequent investigations.

PHYSICAL, BIOLOGIC, AND CHEMICAL FEATURES OF THE MUDS[13]

The following are the results of mechanical analyses of several samples which are about typical of the class of deposit under consideration:

MECHANICAL ANALYSES OF BOTTOM SAMPLES

STATION NUMBER	2–1 MM.	1–0.5 MM.	0.5–0.25 MM.	0.25–0.10 MM.	0.10–0.05 MM.	0.05–0.005 MM.	0.005–0 MM.
B.s. 87	1.0	1.6	1.7	10.2	25.1	25.8	35.4
88	0.6	1.9	4.3	16.1	27.9	19.5	30.3
177	1.6	4.5	5.0	6.3	12.2	31.1	40.1
261	1.2	2.9	4.0	30.4	23.7	11.3	26.3
262	0	0.1	0	0.2	0.5	29.5	69.8

Silt + clay for Nos. 87, 88, 177, 261.....average 55.0 per cent
Clay for Nos. 87, 88, 177, 261.....average 35.5 per cent

Explanation of station numbers:

B.s. 87, Bahamas, 1 mi. w. of w. mouth of South Bight, depth 1 fm.
88, Bahamas, 3 mi. w. of w. mouth of South Bight, depth 8 ft.
177, Bahamas, 2 mi. w. of w. mouth of South Bight, depth 1 fm.
261, Bahamas, 1 mi. w. of w. mouth of South Bight, depth 8 ft.
262, Florida Keys, east of Sugar Loa fKey, north side of Loggerhead Key, depth about tide level.

[12] Carnegie Inst. Washington, Pub. **133**: 136. 1910.

[13] Prof. Richard Field has applied the name "drewite" to the fine-grained deposits in Tortugas lagoon, Carnegie Inst. Washington, Yearbook **18**: 197. 1920, but he does not define the term petrologically, physically, chemically, or otherwise. Later, Dr. E. M. Kindle, Pan-American Geologist, **39**: 368–369. 1923, used the term "drewite", but he also gives no adequate description of it. However, he designated as the typical locality of "drewite", the shallow-sea bottom of the Great Bahama Bank, west of Andros Island. "Drewite" is not recognizable from the definitions of either Field or Kindle. I know from a study of material from the two areas that the "drewite" of Field is not the "drewite" of Kindle. If "drewite" should be accepted as a name, it should be applied to the kind of deposit Field had in mind. It is my opinion that investigations have not yet advanced far enough to warrant any fixed nomenclature for such deposits. If a temporary name is desired, Grabau's term "calcilutite" might be applied to the "drewite" of both Field and Kindle, but Grabau's term was proposed for indurated calcium carbonate muds.

The striking feature of these analyses is the high percentage of particles of silt and clay sizes.

The small amount of material of the larger sizes is composed principally of foraminifera referred to *Orbiculina adunca* (Fichtel and Moll), but there are some *Sorites duplex* (Carpenter) and shells of small mollusks. The intermediate sizes are composed of smaller foraminifera and ellipsoidal aggregates of minute particles of calcium carbonate, mostly aragonite needles.[14] The ellipsoidal aggregates are particularly characteristic of the Bahamian deposits. The finest sizes are aragonite needles[15] and particles so minute as to be visible only with a very high power of the microscope or the ultramicroscope. Many of the small particles show distinctly under polarized light and, therefore, are probable crystalline. The smaller aragonite needles and the other minute particles exhibit vigorous Brownian movement.

As it seemed that there was an appreciable amount of particles of colloidal size in these muds, I requested Prof. Milton Whitney to test several samples for their probable colloidal content.

In the first specimen submitted (b.s. 261) it was estimated on the basis of the adsorption of water vapor that there was 8.6 per cent colloid.

I then submitted about a quart of mud from the west side of Andros Isiand, Bahamas (b.s. 177) in the hope that enough colloid might be extracted for a chemical analysis. Professor Whitney reported:

"In an attempt to separate out colloidal material from the sample at our disposal we used a small high-speed centrifuge the inside dimensions of the bowl being 1.75 inches in diameter, 0.875 inch in radius and the length of the bowl was 7.5 inches. Running this centrifuge at a speed of 28,000 revolutions per minute we obtained a solution of considerable turbidity in which, however, we found a large number of needles which we assumed to be aragonite having a diameter of about one-tenth micron and varying in length from 1 to 4 microns. As the persistence of organized material in liquids passing through this centrifuge at this velocity is very unusual the remainder of the sample was made quite dilute so as to have sufficient volume to pass through our larger centrifuge. The internal dimension of the bowl of this larger centrifuge is 4.125 inches in diameter or 2.0625 inches in radius while the length of the bowl is 22.75 inches. The solution was passed through this centrifuge which was operating at about 17,000 revolutions per minute. In

[14] H. E. Merwin determined these needles to be aragonite.

[15] For photomicrographic illustrations see Vaughan, T. W., Bull. Geol. Soc. Amer. **28**: pl. 47, fig. 6, 1917; and *Coral and the formation of coral reefs*, Smithsonian Rept. for 1917, pl. 32, fig. 3, 1919.

the solution so prepared no aragonite needles could be distinguished by the ultra microscopic nor could any definite evidence be found of colloidal droplets.

"The turbid solutions passing through the small centrifuge were then passed through a Pasteur-Chamberlain filter tube under suction, the material collecting on the outside of the tube being occasionally detached by reversing the current and putting a pressure on the inside of the tube when the material detaches itself and slides off into a dish. This concentrated material was put on a plate that was slightly warm in order to hasten the evaporation of the small amount of liquid when it began to swell up with bubbles evidently CO_2 escaping at a temperature somewhat above room temperature. This was an indication of a considerable amount of bicarbonate being present which may have been formed through the passage of air during the time taken to filter the water off through the Pasteur-Chamberlain tube. As it was evident that some change has occurred in the material it was felt that satisfactory results could not be obtained by carrying the matter further.

"As the conditions in the material seemed to be very delicately adjusted we took some of the original solution that had passed through the smaller centrifuge and which contained what appeared to be small aragonite crystals and passed in CO_2 when the suspended material was entirely dissolved and an apparently clear solution was obtained. One portion of this was put in the vacuum desiccator when a profusion of CO_2 bubbles were given off. A small amount of solids separated out with the escaping of the gas which were found to be calcite. Another portion of this clear solution was gently warmed on a hot plate, somewhat above the room temperature, to drive off the CO_2. A number of crystals formed which under the ultra microscope were identified as a mixture of calcite and aragonite needles."

In compliance with a suggestion from Professor Whitney, I requested Dr. Paul Bartsch to get for me a large sample of mud at a locality along the Florida Keys where I knew the material was very fine grained. This specimen contained 69.8 per cent of particles of clay size but the percent of colloid has not yet been determined.

The results of these tests was to show that much of the fine material in these samples consists of particles of colloidal size, thereby corroborating an inference that would be drawn from the Brownian movement so well exhibited.

The Bahamian samples differ from the Floridian samples by having a far greater abundance of neat, very distinct aragonite needles. There are some aragonite needles in the Floridian samples, but many of the small particles appear to be rhombs and are probably calcite, but this feature needs more careful study.

CHEMICAL COMPOSITION OF THE MUDS

The following are chemical analyses of several of the muds and specimens of oolite:

CHEMICAL ANALYSES OF OOLITE AND BOTTOM SAMPLES FROM FLORIDA AND THE BAHAMAS*

(By W. C. Wheeler)

	OOLITE, BOCA GRANDE KEY, FLORIDA	OOLITE, EVERGLADES, MIAMI, FLORIDA	OOLITE, SHARP POINT, ANDROS ISLAND	BOTTOM SAMPLE† (93), EAST SIDE MARQUESAS LAGOON, FLORIDA	BOTTOM SAMPLE‡ (87), 1 MILE WEST OF WEST END OF SOUTH BIGHT, BAHAMAS
	per cent	*per cent*	*per cent*	*per cent*	*per cent*
SiO_2	0.03	8.23§	0.07	1.13	0.28
Al_2O_3	0.18	0.00	0.00	0.14	0.03
Fe_2O_3	0.22	0.21	0.13	0.21 (total Fe)	0.11 (total Fe)
MgO	Trace	Trace	Trace	1.31	1.25
CaO	53.77	51.60	54.57	51.04	52.30
Na_2O	0.90	0.11	0.14	.....	.....
K_2O	Trace	Trace	Trace	.....	.....
H_2O	1.21	0.17	1.72	2.03 (and organic)	3.16 (and organic)
CO_2	42.34	40.11	43.07	41.50	42.45
P_2O_5	Trace	Trace	Trace	.....	.....
SO_3	0.28	Trace	0.14	.....	.....
Cl	1.02	0.08	0.03	.....	.....
Soluble	....	....	....	2.21‖	.....
Total	99.95	100.51	99.87	99.57	99.58

Reduced analyses (hypothetical combinations); H_2O, organic matter, and soluble salts rejected; silica not essential

SiO_2	0.03	8.19	0.07	1.18	0.29
$(Al, Fe)_2O_3$	0.42	0.21	0.13	0.37	0.15
$MgCO_3$	Trace	Trace	Trace	2.88	2.72
$CaCO_3$	99.05	91.60	99.56	95.57	96.84
$Ca_3P_2O_8$	Trace	Trace	Trace	.....	.....
$CaSO_4$	0.50	Trace	0.24	.....	.....
Total	100.00	100.00	100.00	100.00	100.00

* Vaughan, T. W., Geol. Soc. Amer. Bull., **28**: 937. 1917.

† Sample washed and dried over H_2SO_4.

‡ Sample filtered, washed, and dried ever H_2SO_4.

§ Twenty-five per cent soluble SiO_2; the rest of the silica appears to be white sand.

‖ Saline salts not washed out by water in the preparation of the sample.

SAMPLE OF MUD FROM THE BAHAMAS, B.S. 261.

(Chemical analysis by E. Theodore Erickson)

		CALCULATED AS:	
SiO_2	0.22	SiO_2	0.22
Al_2O_3	0.21	Al_2O_3	0.21
Fe_2O_3	0.06	Fe_2O_3	0.06
MgO	0.66	$CaCO_3$	89.62
CaO	50.19	$MgCO_3$	1.39
H_2O	0.79	$SrCO_3$	0.93
		$CaSO_4$	0.68
Organic matter and H_2O +	5.86	Organic matter and H_2O +	5.86
TiO_2	None		
CO_2	40.60	H_2O	0.79
P_2O_5	Trace	$(Ca)_3(PO_4)_2$	Trace
SO_3	0.51	MnO	Trace
MnO	Trace	TiO_2	None
SrO	0.63		
	99.73		99.73

Ignited insoluble ..... 0.35 per cent
Ignited insoluble, other than SiO_2 ..... 0.13 per cent

When received at the chemical laboratory this sample was "pasty" with an excess of moisture. It was dried to "apparent" dryness at 105°C. for several hours and the above analysis was then made on the dried sample.

It is interesting that strontium is present in this sample.

An examination of sample, b.s. 261, Andros Island, Bahamas, by Mr. Erickson showed the presence of organic matter, but neither its amount nor its nature was ascertained.

Prof. Milton Whitney had a partial chemical analysis and a determination of the water-adsorption value made of the colloidal part of b.s. 262 from Florida and reports as follows:

PARTIAL CHEMICAL ANALYSIS OF COLLOID FROM B.S. 262.

	PER CENT	REJECTING LOSS ON IGNITION
SiO_2	2.78	8.02
(TiO_2, Fe_2O_3, Al_2O_3, P_2O_5	2.86	8.25
CaO	20.15	58.10
MgO	8.89	25.63
Loss on ignition	62.04	.....
Total	96.72	100.00

It is interesting to note that the mineral part of this material is mostly composed of calcium and magnesium salts, of which the calcium are more than twice the amount of the magnesium salts, and that SiO_2 and $Fe_2O_3 + Al_2O_3$ together aggregate less than one-third of the amount of the CaO. The MgO content is relatively high and differs significantly in amount from that found in the oolitic limestones. It appears that there are chemical features of these muds that are as yet far from being understood and that additional research is needed.

THE LOCUS OF CHEMICALLY PRECIPITATED $CaCO_3$ IN THE OCEAN

The shoal-water calcium-carbonate deposits have now been studied for several areas in tropical and subtropical regions. Dr. M. I. Goldman made a very detailed study of the reef sands of Murray Island, Australia, and later he has made a similar study of sands collected behind the reef at Cocoanut Point, Andros Island, Bahamas; and M. N. Bramlette has just completed a quantitative determination of the different ingredients of the bottom samples of Pago Pago Harbor, Samoa. No chemically precipitated calcium carbonate was recognized in any of the samples from the three localities mentioned. Besides these detailed studies by Messrs. Goldman and Bramlette, I have examined numerous bottom samples in a more or less cursory way. The chemically precipitated material, which is identified chiefly by the aragonite needles, is known only under peculiar environmental conditions. The present sites of its undoubted occurrence are chiefly the shallow mud flats on the leeside, the west side, of Andros Island, Bahamas, and some of the flats behind the Florida Keys. Many of the samples I have collected need to be restudied in the light of the wider experience acquired since the investigation of such deposits was undertaken, and the present known extent may be somewhat increased.

The natural environment of the deposits is shallow, relatively stagnant water, which may at times be heated by the sun above the normal temperature of the freely circulating ocean water; the salinity of a spot sample of water from the west side of Andros Island is more than 2 parts per thousand higher than that of the normal ocean water of the region; and there is considerable organic matter in the mud.

CAUSE OF THE PRECIPITATION OF THE CALCIUM CARBONATE

In 1910 I suggested that the precipitation of $CaCO_3$ in the Florida Key region was due to loss of CO_2 because of mechanical agitation and the action of marine plants.[16]

[16] Carnegie Inst. Washington, Pub. **133**: 135. 1910.

The investigation had advanced to this stage when G. Harold Drew came to Tortugas in 1911 to study the possible effects of denitrifying bacteria on the abundance of green marine plants. He told me that he had discovered that these organisms caused the production of ammonia; and then, as the papers of Murray and other were known to me, I suggested to Drew that he perhaps had discovered the agency whereby the precipitation of calcium carbonate in the Florida Key region was effected, and he accordingly undertook a series of cultures to test the action of the denitrifying bacteria, to which he applied the name *Bacterium calcis*, without having studied the morphology of the organism.

Drew's principal paper on the subject was entitled, *On the Precipitation of Calcium Carbonate in the Sea by Marine Bacteria, and on the Action of Denitrifying Bacteria in Tropical and Temperate Seas*, in which he expressed the opinion. . . . "it can be stated with a fair degree of certainty that the very extensive chalky mud flats forming the Great Bahamas Bank and those which are found in places in the neighborhood of the Florida Keys are now being precipitated by the action of the *Bacterium calcis* on the calcium salts present in solution in sea water."[17]

Assuming that Drew's conclusions were valid, I concurred in his opinion and published such concurrence in several papers.

After Drew's unfortunate death in 1913, Messrs. K. F. Kellerman and N. R. Smith of the U. S. Department of Agriculture undertook further investigations of the bacterial floras of the Bahamian muds and their possible influence in precipitating calcium carbonate. These investigators[18] isolated Drew's *Bacterium calcis* and found that it is referable to the genus *Pseudomonas*, the name thereby becoming *Pseudomonas calcis* (Drew) Kellerman and N. R. Smith.

Kellerman and Smith recognized that the organic salts of calcium, the malate and succinate used in cultures by Drew, could not reasonably be expected to be present in significant amounts in sea-water, and, therefore, devised cultures in which the only additional supply of calcium to the sea-water was calcium sulphate contained in a suspended dialyser. The denitrifying organisms were grown in association with CO_2 producing organisms, so that the conditions

[17] Carnegie Inst. Washington, Pub. **182**: 44. 1914.
[18] Journ. Wash. Acad. Sci., **4**: 400–402. 1914.

would be favorable for the reaction

$$CaSO_4 + (NH_4)_2CO_3 = CaCO_3 + (NH_4)_2SO_4$$

and abundant precipitation of calcium carbonate resulted.

These experiments seemed fairly conclusive that denitrifying bacteria might be an agency in precipitating calcium carbonate in particular areas in the ocean. But Prof. C. B. Lipman, from studies he made in Samoa and later at Tortugas, Florida, reached the conclusion that denitrifying bacteria do not cause the precipitation of calcium carbonate in "pure sea water." However, as he says that "calcareous sand inoculation showed marked nitrite production,"[19] he thereby indicated that he recognized a difference between conditions in the open ocean and on the shallow sea-bottom.

In the report of the Committee on Sedimentation of the National Research Council for 1923, pp. 33–37, statements by N. R. Smith and me bring the matter as regards the Bahamian and Floridian bottom deposits up to date to April, 1923. *Pseudomonas calcis*, from present information, is principally a bottom-living organism and it seems to thrive best on a bottom in which there is considerable organic matter in the mud. The investigations are deficient in that the nature of the organic matter in the mud is still unknown, and until this deficiency is supplied satisfactory conclusions may not be expected.

There is no reason to challenge the accuracy of Professor Lipman's work or his conclusion that denitrifying bacteria do not cause the precipitation of calcium carbonate in "pure ocean water." But it seems that he has not conducted experiments under conditions which would simulate those under which the particular kind of deposit whose cause is sought is known to occur.

In May, 1922, Dr. Paul Bartsch collected an additional large sample of mud off the west side of Andros Island, Bahamas, for me, and through the kindness of Dr. K. F. Kellerman, N. R. Smith, of the Bureau of Plant Industry, undertook another study of the bacterial flora of the mud. Mr. Smith has completed an elaborate investigation and I quote from his report:

"All the colonies on three plates were picked off and put into media for pure culture work. A comprehensive and critical study of their activity showed them to belong to three large groups based upon their biochemical relations."

[19] Lipman, C. B., *Does denitrification occur in sea water?* Science, n. s. 56: 501–503. 1922.

TABLE I.—GROUPS OF BACTERIA IN B.S. 261

"Group I.		Denitrifiers.	*Ps. calcis* type.
"Group II.		Ammonifiers.	
	A. Vibrios.	Strong Ammonifier	
	B. "	Weak "	
	C. Rod-forms.	Weak Ammonifiers—Gram Negative.	
	D. "	Weak " —Gram Positive.	
"Group III.	Inactive forms".		

"The precipitation of calcium carbonate in natural and artificial sea water by mixed crude cultures from the mud and by pure cultures is given in Table III. Various sources of food for the bacteria are indicated. In each flask, a dialyzing tube containing calcium sulfate was suspended to keep a supply of calcium in solution."

TABLE II.—CALCIUM CARBONATE PRECIPITED IN SEA WATER

NUTRIENTS ADDED	INOCULUM	$CaCO_3$
(1) Peptone 0.2%; KNO_3 0.2%	Crude cultures	Many crystals
(2) " " ; " "	Group I	" "
(3) 2 gm. cooked egg albumen	Crude cultures	Crystals.
(4) 2 gm. " " "	" "	"
(5) 2 gm. " " "	Group I and II A	Many crystals
(6) Sterile mud in dialyzing tube	" I and II A	Few crystals
(7) " " " " "	Crude cultures	Very few crystals
(8) " " " " "	None	No crystals
ARTIFICIAL SEA WATER		
(10) Peptone 0.2%; KNO_3 0.2%	Group I	Few crystals
(11) " " ; " "	Crude cultures	Many crystals
(12) KNO_3 0.2%; " "	" "	Few crystals
(13) Peptone 0.2%; agar 0.2%. " "	Crude cultures	Many crystals and aggregates
(14) Peptone 0.2%; agar 0.2%. " "	Group I	Many crystals and aggregates
(15) Peptone 0.2%; " "	Group I and II A	Many crystals and aggregates

"One objection might be raised to the above experiments as a whole, and that is that a dialyzing tube of calcium sulfate was suspended in each flask. Also, only Group I and II-A were used for the pure culture inoculations. The following experiment therefore was set up and the results are given in Table III. Sea water with 0.02% K_2HPO_4 was used as a base, the nutrients being as indicated in the table. Plus marks indicate production of $CaCO_3$ and zero's indicate none."

TABLE III.—INOCULATED BY PURE CULTURES OF GROUP

Nutrients.....	I	II-A	II-B	II-C	III
Peptone 0.2%.....	0	+++	0	0	0
Peptone 0.2%.....			0	0	0
KNO_3 0 2%.....	+	+++			

"As can be seen from a glance at the table, Group II-A in pure culture precipitated by far the greatest amount of $CaCO_3$ and Group I only precipitated $CaCO_3$ when nitrates were present. Even then the amount was comparatively small. A rough analysis of the solution in the flasks of Group II-A after the precipitation of the $CaCO_3$, showed only about half the amount of calcium of the control flask.

"From the foregoing, the following points seem to be the most important.

"1. The bacteria of sea water or bottom mud from the mud bank may be grouped into 6 main groups according to their physiological activity.

"2. Calcium carbonate is formed from calcium sulfate as a result of the growth of the bacteria; the more plentiful the food, the better is the chance for the formation of $CaCO_3$. Bottom mud provides a nutrient for the production of a small amount of $CaCO_3$.

"3. Agar in low percentage favors the formation of larger accumulations of crystals of $CaCO_3$.

"4. $CaCO_3$ is formed in natural sea water by pure cultures if organic matter is added."

These experiments show that bacteria taken from a bottom mud largely composed of chemically precipitated material will precipitate $CaCO_3$, and that the mud contains nutrient material that will support the bacteria. It also appears that the strongly ammonifying *Vibrios* are probably more important agents than the denitrifying *Pseudomonas*.

Although the researches of Mr. Smith have advanced knowledge of the possibility of the precipitation of calcium carbonate by ammonifying bacteria, other entirely inorganic factors need to be considered. Johnston and Williamson have made careful studies of the solubility-product constant $[Ca^{++}]\,[CO_3^{=}]$, the concentration of H_2CO_3, the effect of temperature on H_2CO_3 concentration, and the relation of the solubility-product constant to rise in temperature;[20] R. C. Wells has conducted experiments on the solubility of calcite in sea-water;[21] and the relative saturation of sea-water with reference to $CaCO_3$ has been studied or discussed by a number of other investigators, including myself. The results of the different investigators are accordant, and all agree that the surface layers of the ocean water in tropical and subtropical regions is saturated or even super-saturated with reference to $CaCO_3$, and that any agency that would cause a further concentration of $CaCO_3$, or which would otherwise reduce the capacity of the water to hold $CaCO_3$ in solution, would produce pre-

[20] Johnston, J., and Williamson, E. D., *The role of inorganic agencies in the deposition of calcium carbonate.* Journ. Geol. **24**: 729–750. 1916.

Johnston, J., Merwin, H. E., and Williamson, E. D., *The several forms of calcium carbonate.* Amer. Journ. Sci. **41**: 473–512. 1916.

[21] Carnegie Inst. Washington, Pub. **213**: 316–318. 1917.

cipitation. Where the chemically precipitated $CaCO_3$ is known to be present, there are several such agencies. Two of them are evaporation and increased temperature, at least during the summer months. The action of green plants in reducing the CO_2 content of the water is also an important factor in certain localities. Therefore, theoretically there should be precipitation of $CaCO_3$ without any bacteria.

The different factors entering into the problems have not been evaluated and we stand now about where we did in 1916, except that advances have been made in knowledge of the physical and chemical features of the deposits and of the bacterial flora associated with them. That ammonifying bacteria, with or without the associative action of CO_2 producing bacteria, are responsible for part of the work seems reasonable. By associative action the reaction between $(NH_4)_2\ CO_3$ and $CaSO_4$ may become possible. Perhaps assistance may come from a physical chemist who is an expert on equilibria or through such a physical chemist working in conjunction with a bacteriologist.

I wish to close the account of this subject by a quotation from Murray and Hjort's *Depths of the Ocean*, and a comment on their statement. They say:

"Dittmar's item $CaCO_3$, which was presumably included in order to express the fact that there is on the whole an excess of bases over acids, is obviously incomplete as it stands. From the most recent measurements we gather that a 3 per cent sodium chloride solution, in equilibrium, as regards CO_2-tension, with air (which holds good approximately for sea-water), dissolves at 25°C. about 0.07 gr. of calcium carbonate per litre. Hence there cannot be as much as 0.13 gr. per litre in sea-water [referring to Dittmar's hypothetical combinations in his analysis]. The surplus base should rather be regarded as a mixture of calcium and magnesium bicarbonates, existing in equilibrium with a certain amount of free CO_2, and of the products of their hydrolytic dissociation, viz., calcium and magnesium hydroxides. It is the two latter which impart to sea-water its alkaline reaction.

"On considering sea-water in its relation to submarine deposits we note that, of all possible combinations of cation with anion, there are three which are much less soluble than any others, and are therefore closest upon saturation and precipitation: these are calcium sulphate, calcium carbonate, and magnesium carbonate.

"From what is known of the solubility of gypsum in brines, and allowing for the excess of SO_4, one would suppose that sea-water is

very nearly saturated for this salt, and that addition of, for instance, a sulphate would precipitate it. But gypsum is unknown as a constituent of deep-sea deposits (unless of extraneous origin), so that its solubility-limit is evidently never exceeded under submarine conditions."

Although John Johnston, E. D. Williamson, and R. C. Wells have rendered valuable service in their investigation of the solubility of $CaCO_3$, we do not know the solubility limits of $CaCO_3$, $CaSO_4$, and $MgCO_3$, in the presence of one another in sea-water. Until this problem in physical chemistry has been solved, we shall not be able definitely to understand some important phenomena in the ocean. The relative solubility of the ocean salts, in the presence of one another, is one of the pressing problems of both oceanography and geology.

THE BAHAMIAN AND FLORIDIAN OOLITES

As the study of bottom deposits described to you was prompted by the desire to ascertain the origin of the oolitic rocks of Florida and the Bahamas, I will revert to them for a few moments. For some time I thought the ellipsoidal aggregates in the fine-grained muds were to be considered oolite grains, for in external features they are very similar (see plate I, figs. 1a, 1b, 2), but the grains in the mud do not exhibit the concentric structure of the oolite grains, as plate II, figs. 1–4, shows. However, the cores of the oolite grains are similar to the grains in the muds, and it may yet be shown that the muds represent a stage in the formation of the oolitic limestones. I have expressed this opinion in print, but the opinion was premature. Furthermore, I do not consider the results of my experiments on the growth of grains in the muds trustworthy.[22] The experiments were too crudely conducted.

The origin of the ellipsoidal grains is a puzzle. They resemble in size, form, and general structure, glauconite and greenalite grains, and it is probable that when their formation is explained the explanation will be of wide application. The formation of such aggregates is another of the unsolved problems of oceanography and geology.

OTHER CALCIUM CARBONATE MARINE DEPOSITS

I shall not undertake to indicate the different kinds of shoal-water calcium-carbonate deposits except to state that they are of organic

[22] Vaughan, T. W., Journ. Wash. Acad. Sci. **3**: 303. 1913; Carnegie Inst. Washington, Yearbook **12**: 183. 1914; Carnegie Inst. Washington, Pub. **182**: 83. 1914.

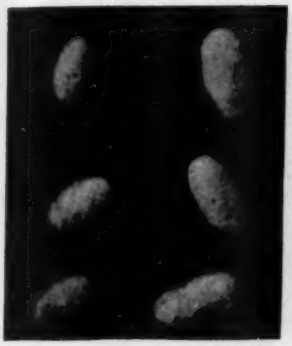
origin, and comprise remains of algal, foraminiferal, coral, echinoid, molluscan, and other organisms. Clarke and Wheeler have made a valuable contribution to knowledge in their work on the inorganic constituents of the skeletons of marine invertebrates and calcareous algae,[23] and Goldman and Bramlette have rendered an important service in their analyses of bottom deposits to determine the percentage of the different organic constituents and correlate organic with chemical composition.

Before passing to the next topic, I wish to emphasize the fact that limestone of a high degree of purity, that is from 95 to over 99 per cent $CaCO_3$, is usually either a very shallow water or only a moderately deep-water deposit. The purest limestone is a very shallow water deposit. It is time that the erroneous statements in text-books that pure limestones are deep-water deposits should be erased. Whether a shoal-water deposit is pure limestone or not is determined not by depth of water but by outwash from the land. Where there is no outwash of siliceous, aluminous, and ferruginous material, beach deposits may contain more than 95 per cent of $CaCO_3$, and the shallow water Key West and Bahamian oolites are over 99 per cent $CaCO_3$. None of the deep-sea deposits nearly approach these deposits in purity.

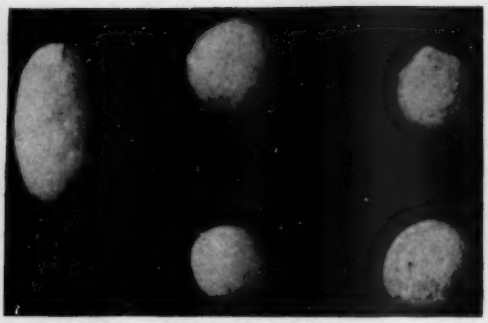
COLLOIDAL CONSTITUENTS OF DEEP-SEA SEDIMENTS

Recently chemical analyses have been made in the Chemical Laboratory of the U. S. Geological Survey by Mr. L. G. Fairchild of about 60 bottom samples collected by the U. S. Coast and Geodetic Survey Steamer "Surveyor" off the Bahamas, across the Caribbean Sea from Jamaica to Panama, and off the southwest coast of Central America to off the southern end of Lower California. These samples show, as had been pointed out by Sir John Murray, a decrease in $CaCO_3$ content with increasing depth. Prof. Milton Whitney undertook the determination of the percentage of material in the colloidal state in these samples by the amount of water vapor adsorbed, and the determinations showed that $CaCO_3$ and material in a colloidal state were reciprocal, the two percentages aggregating about 100 per cent, as is shown in the following table based on specimens of Globigerina ooze:

[23] U. S. Geol. Survey, Prof. Paper 102 (1 ed.); 124 (2 ed.) 1922



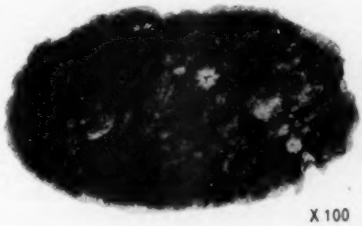
1a X 20



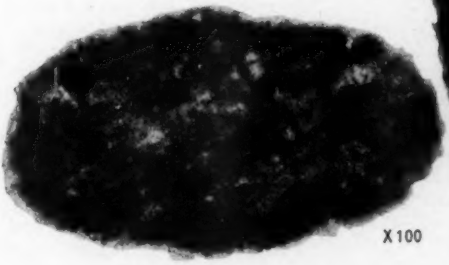
1b X 20

2 X 20

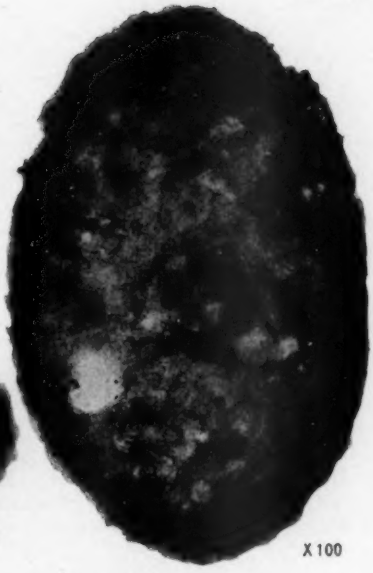
Figs. 1a, 1b. Oolite grains from limestone, No Name Key, Florida.
Fig. 2. Ellipsoidal grains from mud, b.s. 261, Bahamas.



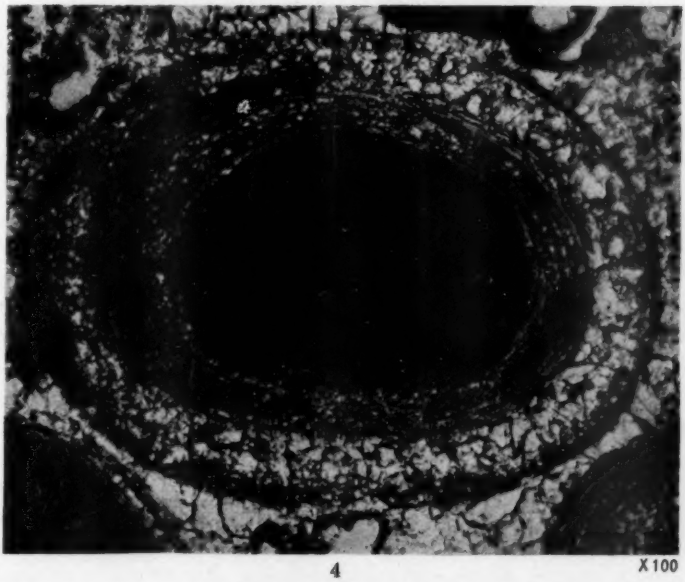
1



2



3



4

Figs. 1, 2, 3. Thin sections of ellipsoidal grains from muds. Figs. 1, 3, b.s. 261, Bahamas, Fig. 2, b.s. 88, Bahamas.

Fig. 4. Thin section of oolite grain, Bahamas.

NUMBER OF SAMPLE	DEPTH	TEMPERATURE °C.	$CaCO_3$*	COLLOID†
	fathoms		*per cent*	*per cent*
6	2,534	2.8	40.20	57.8
7	2,758	2.7	38.02	46.8
8	2,655	2.8	33.45	48.6
9	2,595	2.0	38.42	43.5

* Analyses by L. G. Fairchild.

† Determination by U. S. Bureau of Soils. Method used, absorption of water-vapor.

The tests reported on in the following table were based on composites supplied by Sir John Murray of all samples of red clay and blue mud collected by the "Challenger."

	PER CENT COLLOID	PER CENT NON-COLLOIDAL*	PER CENT $CaCO_3$ (STEIGER)	TOTAL
A. Red Clay.....	63.3	16	8.8	88.1
B. Blue Mud.....	66.5	22	9.2	97.7

* Mr. Fry reports these figures as approximations by counting a number of slides. The non-colloidal material is made up of siliceous animal remains and a few quartz fragments.

I should like to review the investigations of Prof. Sven Odén on the mechanical composition of marine sediments, but I may only state that he has made important contributions to the subject.

The analyses given above present the problem of accounting for the presence of the material in a colloidal state. There are recognizable in our present state of knowledge four possible sources of the colloid, as follows: (1) Outwash from the land; (2) volcanic and other dust precipitated from the atmosphere; (3) the residue from the tests of dead pelagic organisms after their tests have been more or less completely dissolved while falling to the bottom; (4) the mineral residue from the decomposed soft parts of organisms, some of which may be plankton and other deeper, even, bottom-living, organisms. The material is not necessarily derived exclusively from any one of these sources. It seems improbable that outwash from the continents would reach the east side of the Bahamas, but the flocculation and precipitation of particles of colloidal size in sea-water have not been sufficiently investigated to warrant a positive opinion on this possible source. Atmospheric dust, including volcanic dust, deserves careful study and attempts at quantitative estimates of its amount should be made. The test-bearing plankton, *Globigerina* and associated organisms, has not been the subject of comprehensive and detailed chemical study, and, until such studies have been made,

the nature of the residue after the solution of the $CaCO_3$ will not be known. Mr. E. G. Moberg has made chemical analyses of plankton at the Scripps Institution of the University of California, but his investigations are incomplete. He has found an appreciable amount of ash, but its composition is not yet known, or at least the results of the analyses of the ash have not been published.

The problems associated with the finer constituents of deep-sea sediments are fascinating and a number of them can be solved. I should like to discuss them further, but I may not do so on this occasion.

THE GEOLOGICAL SIGNIFICANCE OF SOME BIOLOGIC FEATURES OF THE OCEAN

Many geologic deductions are based on biologic premises. I will briefly discuss three kinds of biologic research that are needed in interpreting sedimentary rocks. These are the rate of growth of rock-forming marine organisms and the ecology and the duration of the free-swimming larval stages of marine organisms.

That marine organisms are important rock builders is known to all students of sedimentary rocks and I have in this address already enumerated the more important groups. The rate at which these agents may build rock is determined by their growth rate. About the only groups of such organisms on which there is at all adequate information are the stony corals and *Alcyonaria*. The stony corals are of more or less romantic interest because of their association with ship-wrecked mariners, feathery palms, and dusky maidens, but the volume of rock attributable to them is relatively small. The other organisms associated with reefs, the nullipores, mollusks, and foraminifera, are fully as deserving of study. If Professor Setchell should give us the data on the nullipores, as it is hoped he will, a considerable body of information will be available on three important groups of organisms in the shoal waters of the tropics. The growth rate of some economically valuable mollusks is known, and these are also rock builders, but much more information is needed. It is desirable to have observations made on the growth rate of all the organisms with hard parts at as many localities as is possible.

The organisms that transcend all others in importance as contributors to sediments are the foraminifera and I am not aware of any information on their growth rate. In fact there is probably no group of organisms on which information for geologic purposes is more greatly needed than the foraminifera. The need for chemical

analyses of the foraminiferal plankton has already been stated; and later they will be mentioned again in discussing the duration of free-swimming larval stages.

Information of the kind indicated is also needed for diatoms. Perhaps Doctor Mann will tell us uninformed geologists, how long it took to form the diatomaceous earths of the Calvert formation in Maryland and Virginia and of the Monterey group in California.

The history of most sedimentary geologic formations is in large measure deduced from premises derived through the study of the ecology of living organisms. The temperature of the seas in which ancient deposits were laid are inferred almost exclusively from biologic evidence. Depth is inferred both from organisms and the nature of the sediments. The intensity of light is inferred from depth and latitude, which controls the angle of incidence of the sun's rays. The character of the motion of the water is deduced from the physical features and arrangement of the sediments and from biologic evidence. The concentration of salts in the water is deduced from the organisms. Each one of these topics might be the subject of an essay.

We need to know for geologic purposes the ecology of all the important groups of marine organisms; and the ecology should not be considered merely in an empirical way but it should be based on the deepest ascertainable mechanical and bio-chemical foundation. Sir John Murray in his treatment of the pelagic foraminifera put before us an ideal toward which we should strive. In order to achieve the desired goal, the bio-chemistry of skeleton formation needs to be thoroughly understood, and I wish to bespeak for Dr. Shiro Tashiro all the encouragement and support his scientific colleagues can give him.

In dealing with problems of geologic correlation, which involve the consideration of the geographic distribution of organisms in past geologic time, the geologist needs to know the factors that limit distribution to restricted areas and the means whereby dispersal over a possible geographic range may be effected. I have devoted considerable attention to this topic in an address before the Paleontological Society and the Geological Society of America, and therefore, need now to treat it very briefly.

Certain fossil marine organisms attained world-wide distribution apparently in a rather short time, geologically speaking. Examples of organisms of this kind are supplied by three genera of larger foraminifera, *Discocyclina*, *Asteriacites*, and *Lepidocyclina*, which are

known in Europe, America, the East Indies, and Asia. Another genus of foraminifera, the large *Nummulites* found in the limestone of which the Egyptian pyramids are built, is not known in America, but it is known in Europe, Africa, and Asia, and as far eastward as the Bonin Islands. In the adult stage all of these organisms are bottom-living. How can such a distribution be explained? The most plausible hypothesis is that the embryos of *Nummulites* are free-swimming for only a short time and, therefore, could not be carried great distances by ocean currents, while the embryos of the other genera could be.

Several species of corals found on the east coast of Africa also occur in the Hawaiian Islands. How is so wide a distribution of corals made possible? At one stage in their life corals are free-swimming larvae and my own experiments showed that some larvae may remain free for as many as 23 days and then settle and form colonies. The long duration of the free-swimming larval stage renders possible wide dispersal by ocean currents.

In order to understand the possible distribution of organisms by marine currents it is necessary to know whether the organisms pass through a free-swimming larval stage and if they do pass through such a stage what the duration of the stage is. Unfortunately relatively little information is available on most groups of organisms. It is, therefore, obvious that one of the desiderata of geology is to know the duration of the free-swimming larval stage and the upper and lower temperature limits the larvae can withstand for just as many groups of marine organisms as is possible. I will specify foraminifera, sponges, corals, echinoderms, bryozoa, brachiopods, and mollusks.

There are other biologic features of the sea of importance to geologists, but I shall not try to enumerate more. I have mentioned three subjects on which far more research is needed before the demands of the geologists on marine biology will be satisfied.

CONCLUSION

In the remarks I have made to you, I have not attempted to outline the content of oceanography, a subject well treated in an address by Capt. R. L. Faris before the Philosophical Society of Washington and published in our Journal.[24] I should like to dwell on some other aspects of the biology of the ocean, particularly the fundamental food supply of marine organisms, and to indicate how it is a field for

[24] Faris, R. L., *Some problems of the sea*, Journ. Wash. Acad. Sci. **12**: 117–132. 1922.

investigation as yet scarcely touched, but I must pass it with bare mention. I should also like to indicate the relation of certain oceaongraphic problems to problems in both geology and engineering, such as the deterioration of concrete in contact with sea-water at and near sea-level and the behavior of the finer constituents of sediments. These problems are mentioned to indicate that this address makes no claim to comprehensiveness.

The discussion of each topic considered in my remarks terminates with the presentation of a set of unsolved problems, some of them of great complexity. It might be inferred that very little is known about the ocean. Such as inference would be a half truth. If we compare what is now known with what was known in the days when Maury was doing his epoch-making work, it will be evident that great advances have been made in knowledge of the ocean. Even since the publication of Murray and Hjort's *Depths of the Ocean* in 1912, many important additions have been made to our knowledge of the ocean. We have advanced and are rapidly advancing in the science of oceanography, but our knowledge of nearly all the fundamentals is deficient. However, until knowledge had reached its present stage recognition of many of the problems was not possible. It is on the unsolved problems, particularly the more fundamental ones, that future investigations should be concentrated.

I have indicated some of the problems of oceanography and have shown that for their solution all the different branches of geophysics must lend assistance and aid must also come from those branches of geology not classified as geophysics. Oceanography in its turn can help the other earth sciences. For geology knowledge of the ocean is essential, because the ocean holds the key to the history recorded in most of the sedimentary rocks.

GEOPHYSICS.—*The distribution of iron in meteorites and in the Earth.*[1] L. H. ADAMS and H. S. WASHINGTON, Geophysical Laboratory, Carnegie Institution of Washington.

It is now generally agreed that the Earth consists of an iron core surrounded by silicate rock. The earlier speculations concerning the density at various distances from the center, it is true, proceeded on the assumptions that the Earth is essentially uniform in composition and that the high internal density is due to compression under

[1] Received June 25, 1924.

the great pressures in the interior. But, beginning with the hypothesis by Dana in 1873, the notion of an iron-cored Earth has steadily gained credence among students of the subject.

What is certainly known is this: somewhere within the Earth is a very considerable amount of material intrinsically denser than any known silicate rock. This conclusion is reached most directly from studies based on the compressibility of rocks and on the velocity with which earthquake waves are transmitted through the Earth. Such studies have yielded a *quantitative* estimate of the increase in density due to pressure at various depths and have shown that, while the effect of pressure on density is a factor not to be neglected, it is nevertheless impossible to explain the high density of the Earth on the basis of compressibility alone.[2] That is, there must be at the center some material which, under normal conditions, would be much denser than ordinary rocks.

The principal reason for assuming the dense material in the interior to be mainly metallic iron is the analogy with meteorites. Most of these visitors from outer space contain large quantities of metallic iron with varying amounts of nickel; and it does not demand an unwarranted use of the imagination to regard meteorites as fragments of disrupted bodies similar to, although probably much smaller than, our own planet,[3] and to reason that the structure and average composition of these bodies are not very different from those of the Earth.

The earlier picture of the Earth's metallic core, as presented by Wiechert,[4] was that of a central iron core separated by a rather sharp boundary from the surrounding silicate shell. More recently[5] it has been suggested that between the core and shell lies a zone of mixed metallic iron and silicate rock, called pallasite from its supposed resemblance to a certain type of meteorites. The stony shell that surrounds the iron core is supposed to be granitic near the surface, and of basic (peridotitic) character below. The probable distribution of iron within the Earth is represented by Fig. 1, which shows the central iron core surrounded by the pallasite layer,[6] above this being the silicate shell, and the outermost, thin rocky crust.

[2] Williamson, E. D., and Adams, L. H., *Density distribution in the Earth*, Journ. Wash. Acad. Sci., **13**: 413–428. 1923.

[3] Farrington, O. C., *The pre-terrestrial history of meteorites*, Journ. Geol. **9**: 626. 1901.

[4] Wiechert, E., Nachr. Ges. Wiss. Göttingen, p. 221. 1897.

[5] Williamson, E. D., and Adams, L. H., Op. cit., p. 424. Also Clarke, F. W., *The evolution and disintegration of matter*, U. S. Geol. Survey, Prof. Paper 132-D: 76. 1924.

[6] This figure is taken from Williamson and Adams, this Journal, **13**: 426. 1923.

The existence of the zone of pallasite is indicated by the course of the earthquake velocities as a function of depth. If these quantities be plotted a striking feature of the graph is that, whereas the velocity increases steadily and rectilinearly down to depths of about 1,600 kilometers below the surface, beyond this depth the velocity becomes almost constant for about 1,400 kilometers. This is accounted for by two facts based on measurements made in the laboratory: 1, the velocity increases with pressure and hence with depth; 2, the velocity is much less in metallic iron than it is in basic silicate

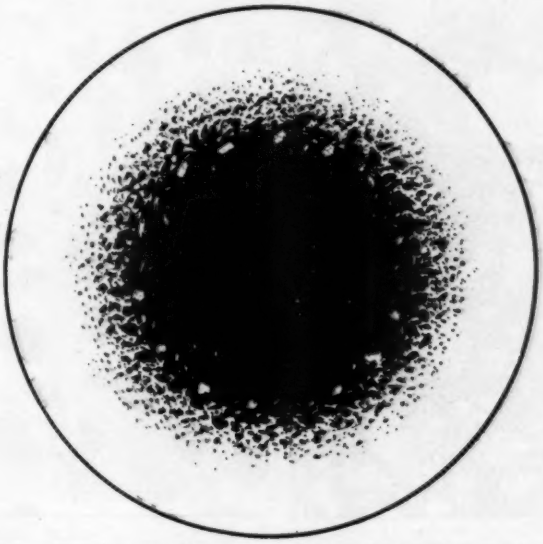


Fig. 1. Cross section of the Earth, showing supposed zone of mixed iron and silicates surrounding iron core. The width of the outer circular line represents, to scale, a surface layer 60 km. in thickness.

rock (peridotite). The small rate of change in velocity at depths below 1,600 kilometers is, therefore, explained as due to the gradually increasing amount of metallic iron mixed with the peridotite, because the normal tendency for depth to increase the velocity in the peridotite is offset by the increasing admixture of iron with a lower transmission velocity. This transition zone between the metallic core and the silicate shell may be thought of as a zone of incomplete segregation.

In view of the supposed similarity between meteorites and the interior of the Earth, it is important to consider more in detail the structure and composition of meteorites.

Meteorites are classified into three main groups: *siderites*, composed almost wholly of nickel-iron; *siderolites*, composed of about equal parts of nickel-iron and silicates, the latter chiefly olivine and orthorhombic pyroxene; and *aerolites*, composed almost wholly of silicates, also chiefly olivine and orthorhombic pyroxene. Small amounts of some non-oxide compounds (sulphides, phosphides, carbides, etc.) are almost always present, but they may be disregarded here.

The metal and the silicates appear to be immiscible and, when solidified, they may be intermingled in two ways: the silicate may

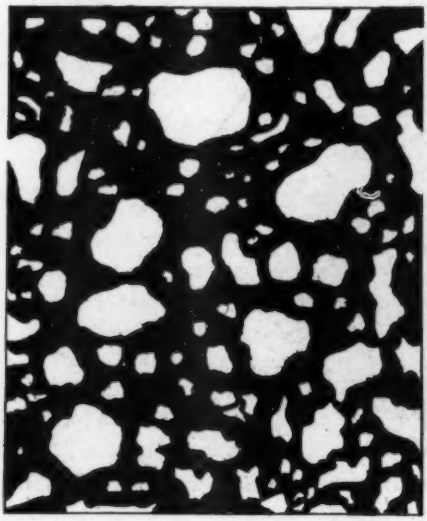


Fig. 2. Diagrammatic representation of a lithospor: silicate scattered, or sporadic, in a continuum of iron.

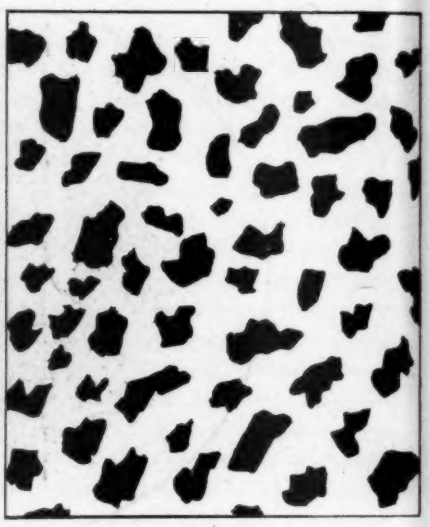


Fig. 3. Diagrammatic representation of a ferrospor: iron scattered, or sporadic, in a continuum of silicate.

be scattered sporadically through a more or less continuous mass of metal, or the metal may be scattered sporadically through a mass of silicates. The former case is illustrated diagrammatically in Fig. 2, and the latter in Fig. 3.

We propose to call the first case, that in which the silicate is sporadic in metal, *lithospor;* and the second, that in which the metal is sporadic in silicate, *ferrospor;* the adjectival forms being respectively *lithosporic* and *ferrosporic.* The material in which the sporadic particles, whether metal or silicate, are embedded would naturally be called the *continuum.*

This distinction between these two types of intermingled iron and silicate was first applied to the classification of meteorites by Daubrée[7] who suggested the terms "syssidères" for those with silicate sporadic in a continuum of iron, and "sporadosidères" for those in which the iron is sporadic in a mass of silicate. Daubrée's terms seem not to have been generally adopted, except by Daubrée's successor Meunier.[8]

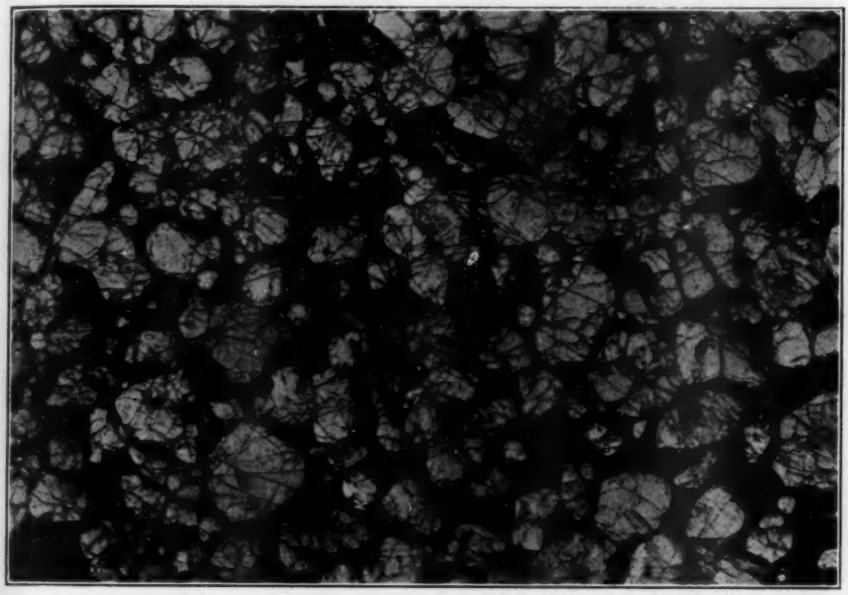


Fig. 4. Actual lithospor (meteoric). Photograph of section of Mount Vernon pallasite. The iron is shown as black.

The now generally accepted classification of Brzina takes little note of the distinction.

These are the two chief, and extreme, modes of intermingling found in meteorites. The lithosporic type is illustrated by the pallasite found at Mount Vernon, Kentucky,[9] (Fig. 4) in which rounded

[7] Daubrée, A., *Classification adoptée pour la collection des meteorites du Muséum*, Comptes Rendues **65**: 60–63. 1867.

[8] Meunier, S., Guide dans la collection des meteorites avec le catalogue des chutes representées au Muséum, Paris, 1898.

[9] We are indebted to Dr. G. P. Merrill, of the U. S. National Museum, for the photographs of specimens in the museum reproduced in Figs. 4, 5a, and 5b. Fig. 4 represents part of Fig. 28 of Merrill's Catalogue of the meteorites in the U. S. National Museum, Washington, 1916.

nodules of olivine are sporadic in a coherent, continuous "sponge" of nickel-iron.[10] This, the most common type of siderolite, is called pallasite. The silicate is usually olivine, much less commonly or-

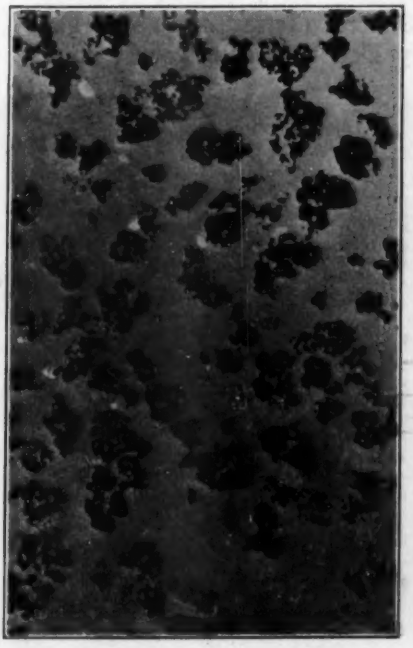


Fig. 5a. Actual ferrospor (terrestrial). Photograph of section of iron-bearing basalt from Kaersut, West Greenland. The iron is shown as black.

Fig. 5b. Actual ferrospor (meteoric). Photograph of section of the Alfianello stony meteorite. The iron is shown as black.

thorhombic pyroxene, or both olivine and pyroxene; but the texture is almost always the same.[11] In the siderites, composed almost

[10] Tassin, W., The Mount Vernon meteorite, U. S. National Museum, Proc. **23**: 214. 1905. From measurements of the areas, Tassin estimates that the percentage of iron is about 36.5 and that of olivine, about 62; his analyses yielded the estimates, respectively, of 33 and 63. Measurements of photographs by Chirwinsky (Mineral. Abstracts, **2**: 84. 1923) gave values of about 41 per cent of iron and 59 per cent of olivene. These are percentages by weight. We estimate, by measurement of the photograph shown in Fig. 4, iron 32 per cent by volume and silicate, 68 per cent, corresponding to the weight percentages, iron, 52, and olivine, 48.

[11] In a sparsely represented sub-group of the siderolites, the "mesosiderites", the metal sponge, although continuous in the mass is separate (discontinous) in thin section: see Farrington, Meteorites, 1915, p. 201, and Merrill, Catalogue of the Meteorites in the U. S. National Museum, 1916, p. 4. This rare type constitutes a transition to the ferrosporic type.

wholly of metallic nickel-iron, the constantly present but small amounts of non-oxide minerals are, similarly, always sporadic nodules in the continuous "sponge" of metal.

The ferrosporic type is represented by two examples, shown in Figs. 5a and 5b.[12] The former shows a specimen of the iron-bearing basalt of Kaersut, West Greenland, in which the iron is of terrestrial origin, its volume percentage amounting to 31; the latter shows the stone which fell at Alfianello, near Brescia, Italy, on February 16, 1883. This meteorite contains (in round numbers) about 44 per cent (by weight) of olivine, 41 of bronzite, 8 of nickel-iron, and 7 of iron sulphide (troilite). The ferrosporic type is characteristic of most aerolites, or stony meteorites, in which the amount of metal averages about 10 per cent.

There is a difference which is more apparent than real with respect to the continuity of the material, whether metal or silicate, in which the other is scattered. In the iron-stone meteorites, the siderolites, the continuum is an apparently uninterrupted "sponge" of metal; but the metal is really made up of separate crystal individuals of several nickel-iron alloys. In the stone meteorites, the aerolites, the continuum is continuous only in the sense that it is entirely silicate, but is composed of separate crystals, grains, or fragments, of one or more different silicates.

The lithosporic pallasites contain from 35 to 75 per cent of silicate, with an average of about 50; and the ferrosporic aerolites contain from about 20 per cent of metal to almost none, the average being about 12 per cent.

The analogy with meteorites not only bears out the hypothesis that the central part of the Earth is composed of nickel-iron and a mixture of nickel-iron and silicate, but it suggests further a succession of metal-silicate textures like those shown by meteorites, distinguished by the sporadicity of either silicate or metal, as is illustrated in Figs. 2 and 3. The size of the discrete particles which make up the lithosporic and ferrosporic material of the Earth may cover a vast range—from microscopic particles to "particles" many hundreds of meters in diameter.

We may suppose, then, that in passing from the center outward the almost wholly metallic core of nickel-iron changes gradually into pallasite, with sporadic silicate. In this region the percentage

[12] Fig. 5a is part of Plate LV, in Phalen, W. C., *Notes on the rocks of Nugsuaks Peninsula and its environs, Greenland*, Smithsonian Misc. Coll. 45, 1904. Fig. 5b is from an unpublished photograph made and given to us by Dr. Merrill.

of silicate gradually increases until the pallasite merges into ferrosporic material with scattered grains of nickel-iron, analogous to the greater number of aerolites. The iron becomes less and less abundant, until at about 1,600 kilometers below the surface the material is entirely silicate rock, free from metallic iron, except for rare examples, such as the iron-bearing basalts of Disko Island and Bühl in Hesse-Cassel.[13]

The Earth, then, is to be conceived of, not as a huge meteorite, but as a body similar to those of which meteorites are but fragments representing different parts of the whole mass. On disruption, therefore the Earth would yield all of the known kinds of meteorites.

PHYSICS.—*Some recent results obtained in standardization of geodetic base line tapes.* L. V. JUDSON and B. L. PAGE, Bureau of Standards. (Communicated by G. K. Burgess.)

The standardization of invar base line tapes or wires is regarded in all countries as a process requiring not only apparatus which is most carefully designed but also a facility and care of manipulation, which is perhaps excelled in ordinary linear measurements only in the comparison or use of the national prototype meters themselves.

The equipment for the standardization of base line tapes at the Bureau of Standards is adequate for testing these tapes with a precision much higher than is yet required for their use in the field. Its present state of development—for in its origin it was essentially field apparatus—is the result of accumulated experience in this Bureau and elsewhere. It is a comparator having many merits which it is hoped may be described in a publication in the near future.

There are, however, certain results of recent standardizations of tapes which are of sufficient importance to be discussed at this time in a separate article. In a recent test of six 50-meter invar tapes for the U. S. Coast & Geodetic Survey, a standardization was made during the last week in March. As these tapes were new and as certain tapes received just previously had been found to be unstable as to length, it was decided to keep the tapes for further standardization. The latter work was done on the first of May. A day's work included for separate determinations of the lengths of the tapes

[13] Somewhat similar ideas as to a gradual change from lithosporic pallasite to ferrosporic material between the metallic core and the outer crust have been suggested by Clarke, Op. cit., p. 77, and by Chirvinsky, Op. cit., p. 84.

when supported at three points and when supported at five points. The results summarized in Table I give a fair conception of the consistency of the results obtained in this important field of standardiza-

TABLE I

TAPE NUMBER	CORRECTION TO TAPE WHEN SUPPORTED AT THREE POINTS			CORRECTION TO TAPE WHEN SUPPORTED AT FIVE POINTS		
	March 26th and 27th 8 Determinations	March 26th, 27th and May 1st. 12 Determinations	V	March 26th and 27th 8 Determinations	March 26th, 27th and May 1st. 12 Determinations	V
	microns	*microns*	*microns*	*microns*	*microns*	*microns*
1	−3970.0	−3969.0	1.0	−976.0	−973.4	2.6
2	−3809.5	−3814.9	6.4	−800.1	−800.7	0.6
3	−3468.4	−3472.4	4.0	−529.0	−533.6	4.6
4	−3380.6	−3380.4	0.2	−537.6	−537.7	0.1
5	−2939.1	−2939.0	0.1	−334.2	−332.6	1.6
6	−3167.5	−3163.3	4.2	−656.8	−658.9	2.1
Average			2.6	Average		1.9

tion. The observations were made at an average temperature of 25.4°C.

That this consistency is not due to an erroneous standardization on either date being compensated by a change in the length of the tapes is indicated by the fact that a tape used in the standardization work at the Bureau for several years was also measured, and its length

TABLE II

TAPE NUMBER	COMPUTED CORRECTIONS OF TAPE SUPPORTED THROUGHOUT			
	From observations at three supports	From observations at five supports	Mean	V
	microns	*microns*	*microns*	*microns*
1	+66	+65	+66	1
2	+252	+245	+248	3
3	+471	+480	+476	4
4	+447	+446	+446	0
5	+595	+577	+586	9
6	+202	+207	+204	3
Average				4

remained constant to about ten microns, and was entirely consistent with previous results. For this tape the values of V were 25.2μ and and 9.7μ, opposite in sign. The largeness of this quantity compared with those in the table above is easily explained by the character of the line and the general condition of the tape.

There is another result which gives an insight into the relative accuracy which is obtained in the measurement of base line tapes. The correction to the length of the tape when supported throughout can be readily computed if there are known, its weight per unit length and the correction to the tape when supported at three or at five points. For the test of the six tapes already referred to, the corrections when supported throughout were found by computation, and are given in Table II.

This was not a test undertaken with unusual care, but is representative of the standardization of tapes as now being carried out at the Bureau of Standards. Table III gives these data for other tape standardizations of the past few months.

TABLE III

TAPE NUMBER	COMPUTED CORRECTIONS OF TAPE SUPPORTED THROUGHOUT			
	From observations at three supports	From observations at five supports	Mean	V
	microns	*microns*	*microns*	*microns*
7	+2932	+2897	+2914	17
8	−69	−69	−69	0
9	+1391	+1391	+1391	0
10	+1559	+1541	+1550	9
11	+454	+450	+452	2
12	+801	+805	+803	2
13	+1244	+1252	+1248	4
14	+1101	+1128	+1114	14
15	+1498	+1489	+1494	5
16	+490	+477	+488	11
Average				6

The accumulated records of the Bureau of Standards show that these standardizations determine the values not only to a high relative accuracy but also to a high absolute accuracy.

PHYSICS.—*Notes on the graduation of invar base line tapes.* L. V. JUDSON and B. L. PAGE, Bureau of Standards. (Communicated by G. K. Burgess.)

The precision required in modern geodetic measurements necessitates that the lines ruled on tapes be smooth and even, perpendicular to the edge, clearly visible to the naked eye, and yet not deep enough to affect the strength of the tape. Lines have recently been ruled on geodetic tapes with a result which appears to be so satis-

factory that a brief description of the method illustrated by a photograph (×10) (Fig. 1) of one of them may prove of interest. The lines, 20 microns wide, ruled with a special diamond, carefully set to ensure a single, even, symmetrical line were graduated directly on the invar tape after a small section of the tape had been polished. Owing to various characteristics of invar tapes it is found difficult by the use of the ordinary methods to obtain a good line at the edge

Fig. 1. Photograph of ruling on tape. Magnified 10 diameters.

of the tape. This difficulty has been overcome, however, by filing off the edge of the tape, after the lines had been ruled. A specially constructed template was used in order to take off a very small amount and yet enough to cut off the broadened end of the line. The edge of the tape used in measurements is then smooth, and perpendicular both to the surface of the tape and to the line.

BOTANY.—*A new species of* Panicum *found in alfalfa seed.* AGNES CHASE, Department of Agriculture.

In the course of his work in seed investigation Mr. F. H. Hillman of the U. S. Department of Agriculture found Panicum seeds [fruits] in samples of alfalfa seed from the middle western states that did

not agree with those of any species described and figured in the *Revision of Panicum* by Hitchcock & Chase.[1] The fruits and the spikelets found indicated some species of the *Capillaria* group, though the pronounced scar at the base of the fruit suggested *P. filipes* Scribn., of the allied perennial group *Diffusa*. Mr. Hillman and the writer examined all likely species in the Grass Herbarium without finding the fruits sought. The spikelets resembled most closely those of *Panicum barbipulvinatum* Nash, so Mr. Hillman began a systematic examination of specimens of this species from the Middle West and found the fruit with the pronounced basal scar in a plant from Bucklin, Kansas, collected by A. S. Hitchcock in 1892. After that the writer examined all the rest of the material referred to *P. barbipulvinatum* and found six more plants. The seven resemble each other closely, and differ from typical *P. barbipulvinatum* in that they do not have short flowering branches from the base. *Panicum barbipulvinatum*, however (even with these seven segregated from it) is so variable in habit that these seven could not be excluded on their general appearance alone. They differ chiefly in the stouter culms, firmer foliage, stiffer panicle branches with the lateral spikelets on shorter more appressed pedicels, in the well-developed sterile palea, and especially in the larger darker fruit, with a prominent lunate scar at the base.

The discovery of a hitherto unrecognized species by its seed emphasizes the taxonomic value of seed characters. It also goes to show that the differentiation of closely allied species, instead of being of "no practical value," as is sometimes alleged, may be of great importance in applied botany. The eight native species of the *Capillaria* recognized in the Revision, together with *P. tuckermanii* Fern.[2] (the New England form included in *P. philadelphicum* Bernh. in the Revision) and the species discovered by Mr. Hillman, are so closely interrelated that we have sometimes been doubtful whether they are really distinct. *Panicum barbipulvinatum*, in particular, we have regarded as doubtfully distinct from *P. capillare*. Yet in his work Mr. Hillman recognizes this species from the size and shape of its seed, and also an additional form we failed to distinguish.

The mature spikelets and fruits, as found in alfalfa seed, are plumper than those of herbarium specimens. Species of Panicum drop their fruits so readily that in collecting plants with fully mature seed most of the spikelets are lost. In a forthcoming paper by F. H. Hillman

[1] Contr. U. S. Nat. Herb. **15**. 1910.
[2] Rhodora **21**: 112. 1919.

and Helen H. Henry on *Incidental seeds found in alfalfa and red clover* (to be published by the U. S. Department of Agriculture) the spikelets and ripe fruits of the species of the Capillaria group are figured from several view points, showing differences in contour.

Panicum hillmani sp. nov. Plants annual, in tufts of 1 to 6 flowering and 1 to 3 or 4 sterile culms, 18 to 35 cm. tall, erect or recumbent at base, the lower nodes geniculate; culm papillose-pilose below the panicle and below the nodes, otherwise glabrous; sheaths mostly longer than the internodes, papillose-hispid; ligule membranaceous-ciliate, about 2 mm. long; blades erect or slightly spreading, firmer in texture than common in those of *P. barbipulvinatum*, 7 to 13 cm. long, 3 to 10 mm. wide, papillose-hispid beneath, pilose, sometimes sparsely so, on the upper surface; panicle short-exserted at maturity, 10 to 17 cm. long, as broad or broader, less than half the entire length of the plant, the main axis pilose, the prominent pulvini hispid, the branches stiffly spreading, mostly pilose toward the base, the secondary branches spreading at a narrow angle, the ultimate branchlets and pedicels appressed, scabrous; spikelets reddish or brownish at maturity, 2.5 to 3 mm. long, 1 mm. wide, turgid, acuminate; first glume about two-fifths the length of the spikelet, pointed, 3 to 5-nerved, the midnerve minutely scabrous toward the apex; second glume and sterile lemma equal, much exceeding the fruit, 7 to 9-nerved, the nerves minutely scabrous toward the apex, the hyaline sterile palea more than half as long as its lemma; fruit at maturity olivaceous drab, 2 mm. long, 1 mm. wide, elliptic, with a prominent slightly raised lunate scar at the base. (Figure 1).

Fig. 1. Panicum hillmani, two views of spikelet and fruit.

Type in the U. S. National Herbarium no. 1,037,542, collected on "plain, Amarillo, Texas, August 11, 1918" by A. S. Hitchcock (no. 16206).

Distribution: Prairies and plains Kansas to Texas.

KANSAS: Bucklin, *Hitchcock* in 1892; Ulysses, *Thompson* 56.

OKLAHOMA: "Washita or Swanson Co." *Stevens* 1197.

TEXAS: Big Spring, *Hitchcock* 13367; Amarillo, *Hitchcock* 16206; Abilene, *Tracy* 8295; Without locality, *Nealley* in 1889.

Received April 18, 1924.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

PHILOSOPHICAL SOCIETY OF WASHINGTON

899th MEETING

The 899th meeting was held in the Cosmos Club Auditorium, March 22, 1924. It was called to order by President HAZARD with 40 persons present.

Program: CHARLES MOON: *Electrically controlled micrometers.* The paper was illustrated with lantern slides.

The instrument described in this communication was designed for measuring the diameters of cylinders which are to be used as forms for precision inductance standards. The instrument is equipped with electrical control so that it can be placed with the cylinder to be measured in a constant temperature cabinet and measurements taken without opening the cabinet. The essential parts of the micrometer are: (1) a rigid frame: (2) a measuring screw actuated by a tiny electrical motor with reduction gearing; (3) a pressure indicating device which automatically stops the motor when the measuring pressure reaches a critical value.

The frame of the instrument is a heavy iron ring 40 cm. in diameter made from a well aged casting. Great constancy in the diameter of the ring is not necessary because frequent reference can be made to an end standard.

Measuring screw, motor, and reduction gearing: an ordinary metric micrometer head by Slocumb is used as a measuring screw. The index circle is 15 centimeters in diameter and is graduated in 500 parts each representing one micron. The errors of the screw are small and known. A small D.C. motor was built for the drive. The armature is 15 mm. in diameter and weighs 6.2 grams. The gear train from a small alarm clock gives a reduction in speed from 30,000 to 1.

Pressure indicating device: the end of a hardened rod in a steel tube is used as a measuring point opposite the screw. The measuring pressure is determined by the compression of a spring fitted between the rod and tube. When the pressure reaches a definite value the back end of the rod comes into contact with a lever and opens a pair of platinum contacts in the armature circuit.

Tests made with the micrometer show that it is capable of as high precision as can be obtained by hand operated screws with the advantage of remote control. In a series of 30 readings on a 300 mm. end standard the greatest deviation from the mean is 0.1 micron. (*Author's abstract.*)

Discussion. The paper was discussed by Messrs. HEYL, ECKHARDT, PAWLING, GISH, PRIEST, and HAWKESWORTH.

O. S. PETERS: *New developments in electric telemeters.* The paper was illustrated with lantern slides.

Development work has been in progress for several years at the Bureau of Standards on an electrical telemetric device suitable for measuring strains, displacements, forces, and accelerations, of either steady or rapidly varying value, at a distance. Satisfactory progress has been made and apparatus developed of sufficient accuracy and stability for many kinds of engineering measurements. For its operation this device depends upon the displacement-resistance characteristic, or corresponding pressure-resistance characteristic of a series of carbon contacts. The carbon contacts were selected in preference to other means and substances after extensive tests, and after mounting for the carbon had been devised that gave accurate and dependable calibration and sufficient stability to withstand the shocks due to ordinary handling.

Practical applications so far made consist of the following:

1. Measurement of loads in airplane stay cables during flight.
2. Measurement of strains in airship girders during flight and also in laboratory tests and during construction.
3. Tests of bridge members due to live loading.
4. Tests of bridge members in the laboratory.
5. Measurement of pull on the pressure arm of a dynamometer.
6. Measurement of pressures.

The chief advantages obtained over instruments heretofore available for similar purposes are that simultaneous records or readings can be made of strains, forces, and pressures occurring at a number of widely separated points, and that rapidly varying values can be photographically recorded in their true proportions. Measurements can also be made in places that are inaccessible during tests.

With the strain gage type of instrument records of vibratory strains have been made having harmonic frequencies superimposed as great as 570 cycles per second, with the wave shape accurately reproduced and without greater exaggeration of the deflections due to the harmonic than would arise from the characteristic of the recording element. The carbon contacts themselves have been shown to reproduce vibratory strains up to 840 cycles per second. Further research work will be required to find the upper limit of frequency at which reproduction ceases to be accurate, but that just indicated is as great as is likely to be encountered in structural members. (*Author's abstract.*)

Discussion. The paper was discussed by Messrs. PRIEST and GISH.

L. H. ADAMS presented an informal communication, *Calculation of temperature on the thermodynamic scale.*

Thermodynamic temperatures are usually determined by calculating the differences between this scale and the constant-volume or the constant-pressure gas-thermometer scale. This is usually a tedious process; but by graphical integration of a convenient form of equation, the necessary corrections can be calculated with very little effort. (*Author's abstract.*)

P. R. HEYL presented an informal communication. *The history of the determination of the newtonian constant of gravitation.*

A most remarkable instance of the influence of the personal element in scientific work is found in the work of Boys and Braun on the constant of gravitation. Boys worked with the best facilities to be found in London and Oxford University, and obtained a value which he believed trustworthy to 4 figures. No previous experimenters had ever agreed with each other in the second figure. Braun, a man of 80 years of age, a former teacher of physics, retired from service on account of advanced years and physical infirmities, worked in his cell in a monastery in the mountains of Bohemia, and obtained a value agreeing with that of Boys to 4 figures. (*Author's abstract.*)

Discussion. The paper was discssed by Messrs. GISH and PAWLING.

900TH MEETING

The 900th meeting was held at the Cosmos Club, April 5, 1924. The meeting was called to order by President HAZARD, with 45 persons present.

Program: FRANCIS A. TONDORF, S.J., Georgetown University: *The seismogram and its interpretation.* The address was illustrated with lantern slides, and a number of original seismograms were exhibited.

No seismogram is a contribution to the literature of geophysics unless the data which may be deciphered therein can be expressed in absolute units. Such data are not available from grams of unstandardized seismographs. Standardization, therefore, of these instruments by a competent authority, internationally recognized, is a desideratum and would give to our grams an imprimatur for their use in international researches. A one-man interpretation of the registrations of the vibrations of the earth is very unreliable if not worthless. A comparative analysis of grams of the same quake as registered at different observatories, made by a committee of experienced seismologists, would offer material worth the while. Under such a committee

ambiguities in grams occasioned by the superposition on grams of markings not of seismic origin, could be lifted.

It is suggested that such scientific corporations as the National Research Council, the Geophysical Union, or the Carnegie Institution, and the like, inaugurate the above movement. Such would tend to a reorganization of the 35 or more seismic observatories of the United States, now mostly inactive, encourage the founding of new observatories, and materially unravel the mysteries which lurk within the earth's crust. (*Author's abstract.*)

Discussion. The paper was discussed by Messrs. W. BOWIE, HUMPHREYS, HAWKESWORTH, L. H. ADAMS, LAMBERT, and HAZARD.

901ST MEETING

The 901st meeting was held jointly with the Geological Society, at the Cosmos Club, April 19, 1924. The meeting was called to order by President HAZARD with 45 in attendance.

Program: Prof. W. M. DAVIS, Harvard University: *Oceanic problems related to coral reefs.* The address was illustrated with maps and diagrams.

Oceanic problems are numerous and varied. They may be divided into two groups according as they deal chiefly with observable phenomena, or chiefly with theories about observable phenomena; but it should be understood that, in problems of both groups, the main object of study is a search for *facts:* not less so in the group of theoretical problems where the facts have to be recovered from the unobservable geological past by the mental process of logical inference, that in the group which deals with present-day facts, directly observable.

Among the theoretical problems, some are highly speculative; for example, those dealing with the development and the behavior of the ocean floor. Speculation on that problem leads to a comparison between the ocean floor and continental surfaces. If the form of both had been produced only by diastrophism, they would surely be much more uneven than they are now; but as erosion, abrasion, and sedimentation are also operative, the greater part of the continents, even though traversed by various ancient mountain systems once of great height, have been worn down to moderate altitudes, and only the youngest mountains are lofty. Similarly, the greater part of the ocean floor seems to have been aggraded to a relatively smooth surface, even though parts of it may have been formerly deepened in troughs of depression; only the recently depressed troughs are still of great depth.

That the ocean floor is not stable is indicated by the features of mid-ocean volcanic islands; for according as the floor is stable, rising or sinking, the islands, acted on by stream erosion and wave abrasion, will exhibit different forms. Several lines of evidence thus lead to the belief that mid-oceanic volcanic islands as a rule slowly subside.

The sedimentary deposits with which the ocean floor is aggraded come largely from the continents, but also in part from volcanoes. The insoluble waste of the continents is deposited near their coasts in the form of shallow shelves; and here the process of aggradation works with reference to sea-level. Much of the soluble waste, chiefly limestone, is withdrawn from solution by minute, floating pelagic organisms to make their shells, which after the death of their occupants sink to the bottom; and this process of aggradation may be said to work with reference to the average depth of the bottom. But another part of the soluble continental waste goes to form shallow banks with respect to normal sea-level around the mid-ocean volcanic islands of the warmer seas in the form of coral reefs and their lagoon deposits.

Just as the forms produced by erosion and abrasion on volcanic islands in the cooler seas, where coral reefs are wanting, may be used as the basis of inferences as to the movements of the islands and therefore also of the ocean floor from which they rise, so the forms of islands produced in association with coral reefs may be used in similar inferences; and confirmation is thus found for the opinion above expressed that most volcanic islands slowly subside, and hence that the reefs which they bear have been formed according to Darwin's theory of up-growing reefs on subsiding foundations. Only in a relatively narrow marginal belt of the coral seas is evidence found to support the belief that Preglacial reefs have been cut away by the waves of the lowered and chilled ocean of the Glacial epochs; and even there the islands around which the Preglacial reefs were built appear to have subsided during the building.

More direct evidence of the subsidence of a volcanic island during the formation of an atoll above it is found in the case of Antigua, in the Lesser Antilles. This island is believed to represent a tilted-up and beveled-off atoll, in which the basal volcanic rocks now laid bare appear to be of subaerial or shallow-water origin, and in which the covering strata, including several thousand feet of tuffs interbedded with shallow-water limestones, fresh-water cherts, and a heavy series of limestones and marls again of shallow-water deposition, testify conclusively to a progressive subsidence of the volcanic foundation during their accumulation. The thickness of strata thus exposed to examination is about five times as great as the depth of the Royal Society boring in the Funafuti atoll reef in the central Pacific. A better example of an atoll formed according to Darwin's theory and then tilted up and beveled off for examination could hardly be imagined. (*Author's abstract.*)

Discussion. The paper was discussed by Messrs. HAWKESWORTH, BOWIE, PAWLING, MARMER, HECK and others.

902D MEETING

The 902d meeting was held at the Cosmos Club, May 3, 1924. The meeting was called to order by President HAZARD with 60 persons present.

Program: N. H. HECK and J. H. SERVICE. *The velocity of sound in sea water.* (Illustrated with lantern slides.)

The paper is the result of the sound-ranging work of the Coast and Geodetic Survey Steamer "Guide" during the oceanographic cruise between New London, Connecticut, and San Diego, California, in which both authors participated, the former having general supervision of the sound-ranging work.

The use of acoustic methods in hydrography is the result of further development and application of the apparatus developed during the war for anti-submarine work.

The cruise of the "Guide," which lasted 40 days, included the development of Vares Deep, north of Porto Rico, and a hitherto unexplored deep off the coast of Central America and Mexico. During the cruise sonic soundings were taken at frequent intervals, and in numerous cases simultaneous determinations of depth by wire and sonic methods were made, special care being used in both classes of observations.

A study of the results obtained in all depths from 185 to 4617 fathoms and the determination of velocity along the surface as reported by various organizations afforded the basis for developing a practical method of obtaining the theoretical velocity of sound in sea water. This was based in part on the results of the Challenger Expedition and on the results of Ekman as pointed

out by Dr. George McEwen, Scripps Institution, La Jolla, California, who gave valuable assistance and advice. It was shown by Newton's Law

$V = \sqrt{\frac{\text{elasticity}}{\text{density}}}$ can be put in the simple form,

$V = 10^3 v \sqrt{\frac{10}{10^5 dv}}$ where V is the velocity in meters per second, v is the specific volume from Bjerknes' tables for a given condition and dv is the change in specific volume per bar change in pressure as given in the fifth place of the Bjerknes specific volume tables. For any given sounding the velocities are computed for 200 fathom layers and then the mean velocity is considered to be that of the sounding.

The agreement of this formula with known horizontal velocities was shown to be very close. The following agreement was shown in the case of soundings where the physical conditions were determined by the "guide" or were otherwise known. Agreement for depth 2171 fathoms in the Pacific = 0.3 per cent; agreement for 5 soundings near 3000 fathoms in Atlantic = 0.7 per cent; agreement for 3 soundings, 4000 to 4600 fathoms in the Atlantic = 0.9 per cent. Twenty-three soundings in the Pacific, selected without regard to bottom conditions, when computed in part by physical observations of the "Guide" and in part by data obtained from German publications, gave a mean difference between the theoretical and measured velocities of nearly zero. Thirty-eight soundings along the coast near San Diego, with all kinds of bottom conditions gave similar results.

The conclusion is that the theory affords a working basis for determining the velocity of sound from known physical conditions and also shows that in most cases the bottom slope is not great enough to seriously affect the soundings.

It was shown that steep slopes while important geographically and of special interest to the geologist, cover comparatively small horizontal areas as compared with the great extent of the flat areas. Slope determination in sonic work may therefore be considered a special problem. A list of possible sources of error was given.

A program for future development and application of the method was indicated and its strength and weakness was analyzed. The need of physical observations in future surveys was pointed out. It was recommended that all future oceanographic expeditions use the sonic method to the fullest possible extent but that actual velocities of sound be used, and simultaneous wire and sonic soundings be taken at reasonable intervals. The authors are planning to extend this paper and prepare it for publication by the Government to be used for future sonic and radio acoustic work. (*Author's abstract.*)

Discussion. The paper was discussed by Messrs. L. H. ADAMS, HAWKESWORTH, HUMPHREYS, STEPHENSON, W. M. DAVIS, PARKER, GISH, LITTLEHALES, ECKHARDT, HAYES, LAWSON, and others.

A method of radio acoustic position determination was presented by E. A. ECKHARDT and M. KEISER. (Illnstrated with lantern slides.)

This method was developed for the use of and in cooperation with the U. S. Coast and Geodetic Survey.

The position of a ship in coastal waters is determined by measuring its distance from several shore stations at known map points. These distances are obtained by measuring the times in which a sound signal travels through the sea water from the ship to the receiving hydrophones of the shore stations. In practice the sound signal is provided by firing a small bomb at a suitable

depth. The time of firing the bomb is recorded on a chronograph aboard ship. The sound upon its arrival at the shore station hydrophone automatically starts a clock-work mechanism which sends out several radio signals at definite intervals. These are also received and recorded on the chronograph aboard the ship. Other shore stations operate similarly except that the clock-work mechanism staggers the signals so as to minimize the danger of simultaneous arrival and resulting confusion. The shore station apparatus is so designed that by throwing a single switch the station may either be operated by sound via hydrophone or by radio via antenna and radio receiving set. When operated by radio all shore stations are started simultaneously, since the transmission time of the radio signal is small enough to be ignored, and the record on the ship contains the time at which the tripping signal was sent from the ship and the times at which the shore station signals arrived. The intervals read from the chronograph charts therefore give the lags. The time intervals obtained on firing the bomb corrected by these lags give the travel time of the sound. These times multiplied by the sound velocity give the corresponding distances. (*Author's abstract.*)

Discussion. The paper was discussed by Messrs. LAWSON, HECK, HUMPHREYS, and HAZARD.

903D MEETING

The 903d meeting was held at the Cosmos Club Saturday, May 17, 1924. The meeting was called to order by President HAZARD with 35 persons present.

Program: LOUIS A. BAUER. *Correlations between solar activity and atmospheric electricity.* (Illustrated with lantern slides.)

It has been known for many years that certain fluctuations of the Earth's magnetic field vary appreciably with sun-spots. The first one to have raised the question whether atmospheric electricity also might be subject to a sun-spot cycle variation appears to have been Dr. A. Wislizenus, a physician of St. Louis, Missouri, who for 12 years, 1861–1872, made relative measurements of the atmospheric potential-gradient six times daily. As this question is conceded to be of paramount importance in theories of the origin and maintenance of the Earth's negative electric charge, it was thought well worth while to make a preliminary examination of the available atmospheric-electric data, especially those obtained since the method of absolute measurements of the potential gradient was introduced. In view of the many disturbances to which atmospheric-electric results are subject, it was necessary to restrict the investigation to the so-called electrically undisturbed days; these are "fine weather days," or days of no negative potential and no pronounced electric disturbances. The chief conclusions reached at present as based upon observatories where atmospheric-electric data have been obtained for a sun-spot cycle, or longer, are as follows:

1. During the past two sun-spot cycles (1901–1923), the atmospheric potential-gradient and the amplitudes of the diurnal variation and of the annual variation generally increased with increased sun-spot frequency; the increase in the particular electric element considered was about 20 to 25 per cent, on the average, for a change of 100 in the sun-spot number. The correlation coefficient, on the average, was about 0.75.

2. If any reliance may be placed on the very few available series of atmospheric-electric observations, made prior to 1901, hence before the period of absolute observations, then there are some indications that during two pe-

riods, centering about 1855 and 1889, the reversed relationship mentioned in (1) applied. The forthcoming sun-spot cycle will afford opportunity to examine into this matter more thoroughly.

3. An interesting correlation is exhibited by the atmospheric-electric and magnetic data for 1893, which unite in showing a decrease in the electric and in the magnetic activity at the time of maximum sun-spot frequency.

4. There is some indication that highly disturbed days in atmospheric electricity may in general correspond with highly disturbed days in terrestrial magnetism. Interesting correlations are, in fact, found between certain phenomena of terrestrial magnetism, earth currents, and atmospheric electricity that probably must be referred as a joint cause to solar activity.

In view of the theoretical bearings of the questions raised and their general interest, it is very much hoped that the present results will stimulate those in charge of atmospheric electric stations to use all possible care to ensure continuity of strictly comparable data for as long a period as possible. (For fuller publication see June, 1923 issue of the Journal of Terrestrial Magnetism and Atmospheric Electricity.) (*Author's abstract.*)

Discussion. The paper was discussed by Messrs. MAUCHLEY, PAWLING, HAWKESWORTH, HUMPHREYS, and GISH.

S. P. FERGUSSON and R. N. COVERT. *The new standard anemometer* (presented by Mr. Fergusson). (Illustrated with lantern slides and the old and the new standard anemometers were exhibited.)

The investigation described before the Society on December 16, 1922, has reached a stage where announcement can be made of corrections for velocities indicated by the Robinson anemometer used as a standard in America during the past 70 years and of a design for a new instrument, more accurate, rather better structurally, and adaptable to a larger range of uses. The new anemometer is of the three-cup type suggested in 1921 by Dr. J. Patterson of the Canadian Meteorological Office, with whom the dimensions and proportions were discussed, in order that the same standard of measurement might be adopted in the United States and Canada. The rate of the new anemometer is more nearly constant than that of the old and its maximum error does not exceed 5 per cent. It is expected that the new standard will be placed in service as soon as apparatus now in use can be altered or replaced. The change of standard will not bring about conspicuous changes in records of average velocities below 5 meters a second, but a revision of normals for higher velocities and of standards for destructive winds or gales (which as now recorded are 10 to 22 per cent too high) will be necessary. (*Author's abstract.*)

Discussion. The paper was discussed by Messrs. PAWLING, BAUER and HUMPHREYS.

904TH MEETING

The 904th meeting was held at the Cosmos Club, May 31, 1924. The meeting was called to order by President HAZARD with 44 persons present.

Program: ALFRED J. LOTKA, Johns Hopkins University. *Irreversibility—cosmic and microcosmic.* (Illustrated with lantern slides.)

From the standpoint of statistical mechanics the irreversibility of such processes as temperature equalization by simple heat conduction (always from places of higher to those of lower temperature) is, in a sense, only apparent. A flow of heat (by simple conduction) in the opposite direction is, from this standpoint, not impossible, but only extremely improbable. Two model

processes have been described elsewhere by the author which help to present in realistic manner and in full view to the eye the pertinent facts and relations.

Such models have the further advantage that they draw our attention to a somewhat neglected fact, namely, that a species of irreversibility very like that contemplated in thermodynamics plays an important role also in large scale processes; that irreversibility is a real relative thing—is due to restrictions placed naturally (by physical or economic constraints), or arbitrarily, upon the operations permitted. Just as the trisection of an angle is or is not an impossible feat, according as we prohibit or allow the use of instruments other than ruler and compass, so a process may be described as irreversible (in a larger sense) or not, according as we are restricted (by physical or economic constraints) to operations in bulk, or are allowed to operate separately upon individual elements.

Whereas, in the world of molecules, the Maxwell Demon, able to handle individual particles, is a mythological creature, in the world of baseball dimension, say, *we are* all Maxwell Demons, of somewhat varied dexterity. In approaching the study of the field thus opened to our view, the investigation of the course of evolution in a system comprising living organisms, we shall need to haul the Maxwell Demon from his obscure corner in the museum of scientific freaks, out into the limelight at the center of the stage. It is not a matter of impertinent academic speculation what a mythical Maxwell Demon *might* do in a world of molecules, but on the contrary it is a matter most pertinent to the business of life to investigate what actually *does* happen to a multitudinous population of Maxwell Demons of graded discriminating powers, who are thrown together in cut-throat competition in this very real world in which our lot is cast.

A more extended discussion of some of the questions thus raised will be found in the author's forthcoming book "Elements of Physical Biology." (*Author's abstract.*)

Discussion. The paper was discussed by Messrs. HEYL, HAWKESWORTH, TUCKERMAN, and L. H. ADAMS.

J. P. AULT, *Recording Secretary.*

SCIENTIFIC NOTES AND NEWS

New chairmen of divisions in the National Research Council, who assumed office in July are: Division of Chemistry and Chemical Technology, Prof. JAMES F. NORRIS of Massachusetts Institute of Technology; Division of Physics, Prof. JOSEPH S. AMES of Johns Hopkins University; Division of Geology, Dr. C. DAVID WHITE of the U. S. Geological Survey.

Dr. E. T. ALLEN of the Geophysical Laboratory, Carnegie Institution of Washington, is spending the summer months in a study of the fumarole region known as "The Geysers," Sonoma County, California.

The Director of the U. S. Geological Survey represented the Secretary of the Interior at the World Power Conference, held in London, June 28 to July 12. The Geological Survey was represented at the conference by JOHN C. HOYT.

GEORGE C. MARTIN, geologist in the Alaskan Branch of the Geological Survey, resigned July 1.

Dr. ROBERT SIMPSON WOODWARD, ex-president of the Carnegie Institution of Washington, died at his home on June 29, 1924, in his 75th year. Dr. Woodward was born at Rochester, Michigan, July 21, 1849. Following his education as a civil engineer at the University of Michigan, he served with the U. S. Lake Survey, the Transit of Venus Commission of 1882, the U. S. Geological Survey, and finally the U. S. Coast and Geodetic Survey. Leaving the Federal service in 1893, he became professor of mechanics and mathematical physics at Columbia University, New York City. In 1905 he succeeded the late Daniel Coit Gilman as president of the Carnegie Institution of Washington, then but recently founded by Andrew Carnegie. Dr. Gilman's term of office as its first president had been very short, and the real responsibility for formulating the working plans for the development of a new and comparatively untried form of research institution fell upon Dr. Woodward. Following fifteen years of successful administration in this office he retired from active duty in January, 1921. He was a member and ex-president of the ACADEMY and of the Philosophical Society of Washington, having also been president of the American Association for the Advancement of Science and of the American Mathematical Society, and a member of the National Academy and other national organizations. He was the author of many contributions in mathematical physics and astronomy, especially as applied to geodesy and geophysics.

JAMES BOWEN BAYLOR, formerly hydrographic and geodetic engineer of the U. S. Coast and Geodetic Survey, died on May 23 in his 75th year. He was one of the oldest officers of the Survey and one of the few survivors of the cadets of the Virginia Military Institute who fought at the battle of Newmarket. He entered the Coast Survey in 1873 and as an engineer he was intrusted with numerous important missions, among them being the resurvey of the boundary between the United States and Canada. In 1902, he was appointed commissioner by the Supreme Court to trace the boundary between Virginia and Tennessee. He also undertook similar work with respect to Pennsylvania and New York.

JOHN L. BAER, acting curator of American Archeology, Smithsonian Institution and a member of the ACADEMY, died about May 28 in the Darien peninsula while a member of the Marsh expedition exploring this part of the Republic of Panama. He was a graduate of Lafayette College and had been a member of the Smithsonian Institution for about three years. His death was caused by a fever contracted in the region.

CLARENCE L. MEISINGER, meteorologist with the U. S. Weather Bureau and a member of the ACADEMY, was killed on June 2, when a balloon in which he, with Lieut. J. T. NEELY, U. S. A., was conducting observations, caught fire and exploded. He was a graduate of the University of Nebraska and had been a member of the Weather Bureau since 1919.

The U. S. National Museum has received from the National Geographic Society about 1600 well-preserved bird skins, mostly collected in the high mountains of Yunan and western Szechuen provinces, China, by J. C. ROCK. The collection contains many birds and several genera new to the national collection and is one of the largest and finest collections ever brought to America from China.

XEROX